

From Pixels to Information: Remote Sensing for Planning

May 2008

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National Operations Center

What is Remote Sensing?

- Science and Art of measuring an object, area, or phenomena without direct contact with that object



Context



The Ideal Remote Sensing System

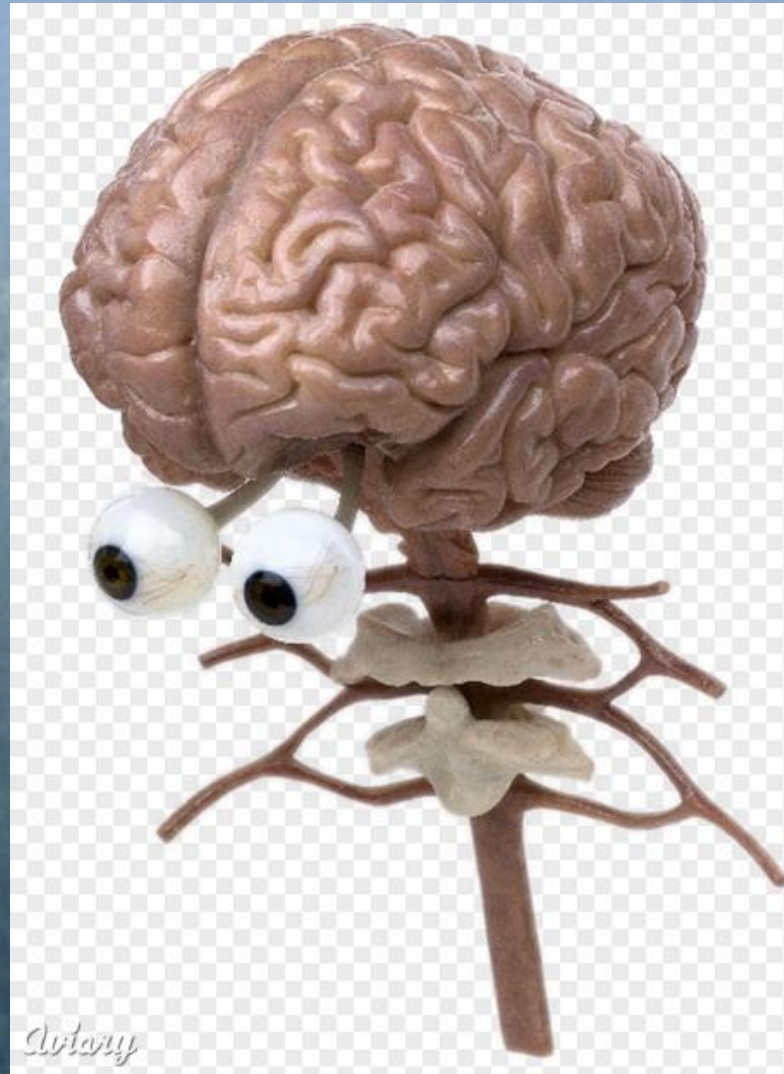


Image Interpretation Elements

- Size
- Shape
- **Tone/Color**
- Texture
- Shadow
- Association
- Pattern

We use each of these image attributes, often subconsciously, to derive information about features in an image, i.e., Photo Interpretation...

Traditional classifiers only use Tone/Color to extract features from imagery.

New technologies use some form of Size, Shape, Tone/Color, and Texture for image feature extraction...

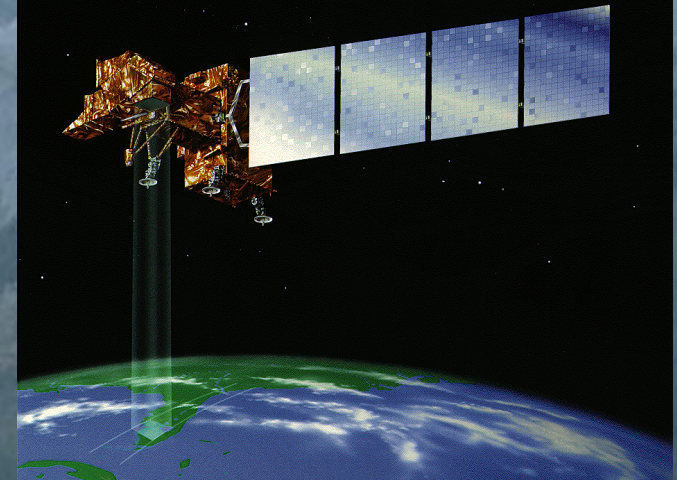
Source: USFS RSAC

How does it help planning?

- Baseline Data
 - Vegetation Mapping
 - Update Vector Layers
- Monitoring / Change Detection
- Decision Support Tool
 - Treatment Effectiveness
- Support for Cumulative Effects Analyzes
- Visual Documentation
- Climate Change

Monitoring change over time

- Traditionally the majority of BLM's monitoring activities have been field-based.
 - Provides great site-specific data
 - Difficult to extrapolate these data to coarser scales
 - Monitoring sites are infrequently visited
 - Driven by permitting not ecology
- Need to develop sampling strategies that allow BLM to effectively monitor multiple scales.
- Remote sensing provides data to fill-in the gaps both spatially and temporally

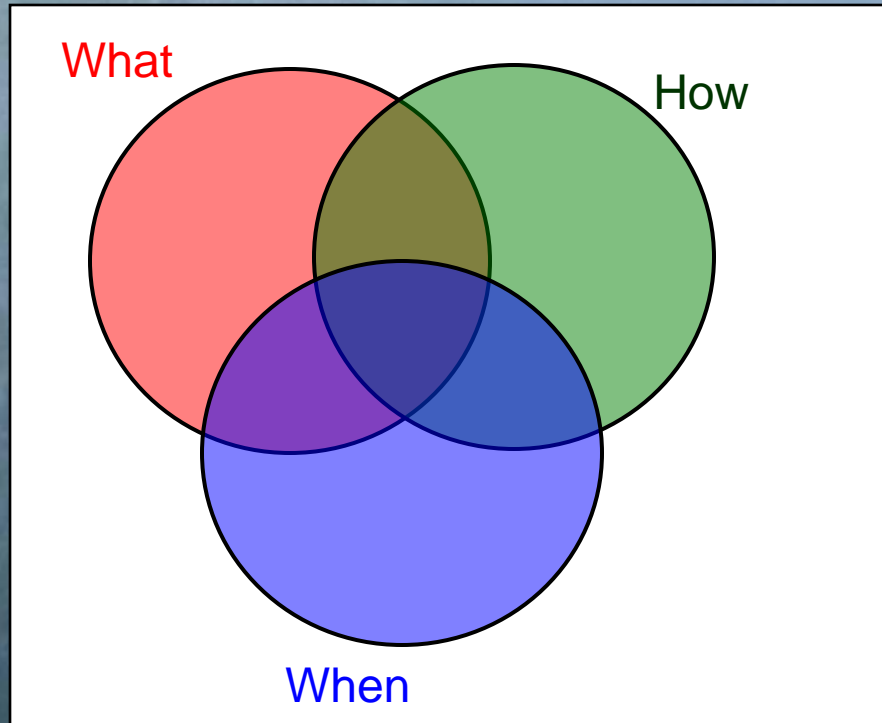


Remote Sensing Project Requirements

- Tripartisan Perspectives
 - Resource Specialist
 - Manager
 - Remote Sensing Geek
- Balance needs to be found
- Define expectations

Requirement Considerations

The Resource Specialist Perspective



What to measure

- What are the issues to be addressed
- What resources are involved
- Extent of resource
- Goals/Objectives

How to measure

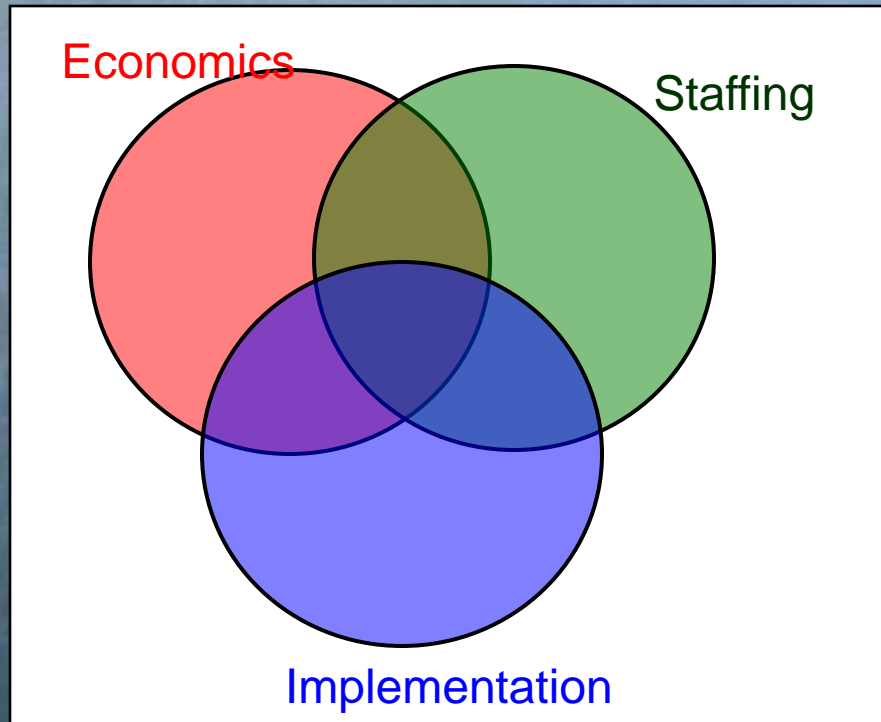
- Indicators
- Mapping verses Sampling
- Accuracy/Detail Requirements
- Scale

When to measure

- Phenology
- Triggers

Requirement Considerations

The Manager Perspective



Economics

- Costs
- Benefits
- Long-term verses Short-term
- Risk tolerance

Staffing

- Training
- Availability
- Commitment
- Partnerships

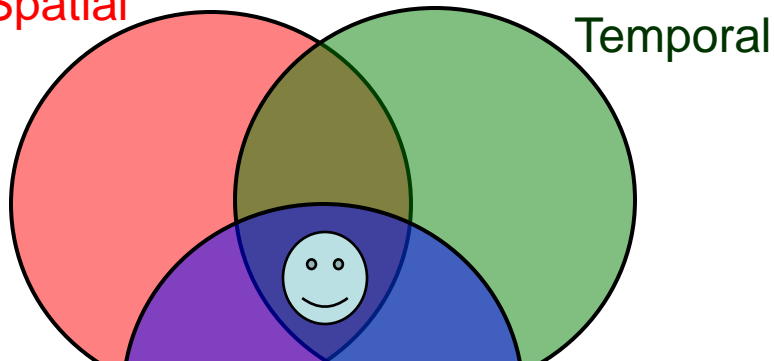
Implementation

- Single Inventory v. Monitoring
- Action Thresholds
- Existing Data

Requirement Considerations

The Remote Sensing Geek Perspective

Spatial



Spatial

- Pixel Resolution
- Swath Width
- Data Volume



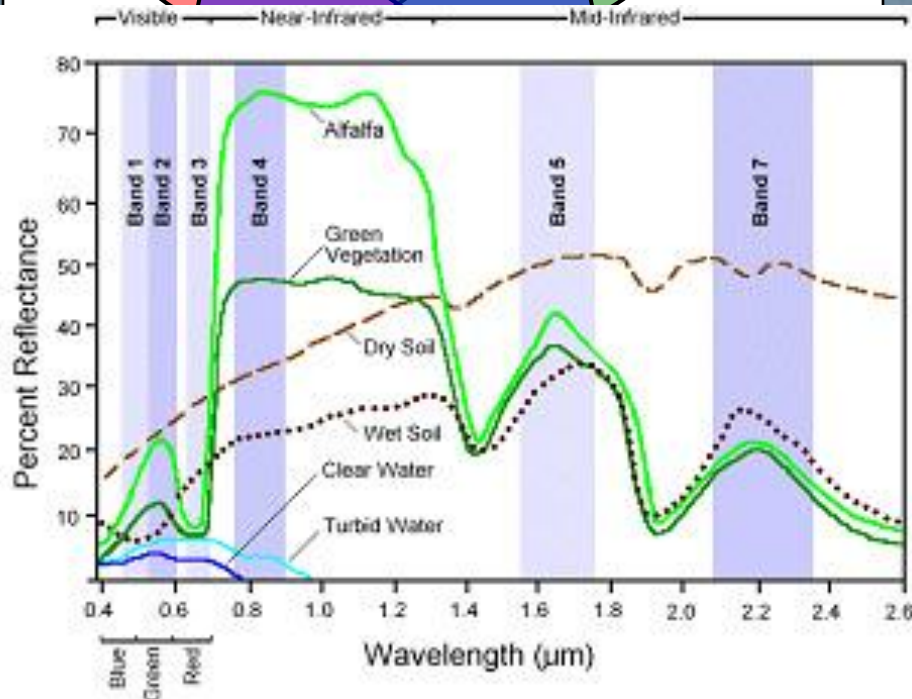
Temporal

- Return Interval
- Seasonality
- Imaging Frequency



Spectral

- Number of bands
- Bandwidth



National Operations Center
Division of Resource Services



Mapping Surface Disturbance

- Inventory of disturbance at multiple resolutions
- Habitat fragmentation
- Cumulative impact
- Monitor to detect change
- Numerous field offices are exploring remote sensing options
 - WO, NOC, SO, FO need to ensure consistency

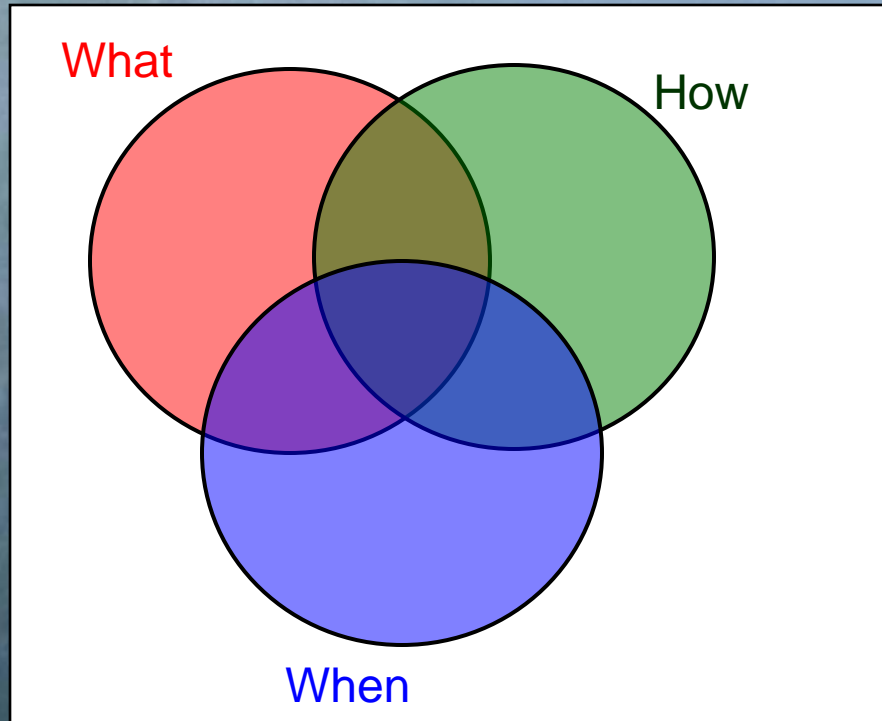


White River Field Office

- Developing Plan Amendment to Monitor Oil/Gas Development
- Need to quantify acres of disturbance per year
- Want to track reclamation progress
- 600,000 acres
- Working with AIM, NOC, and 3rd Parties to develop a scientifically sound and defensible monitoring protocol

Requirement Considerations

The Resource Specialist Perspective



What to measure

- Surface disturbance, Vegetation
- Annual grasses

How to measure

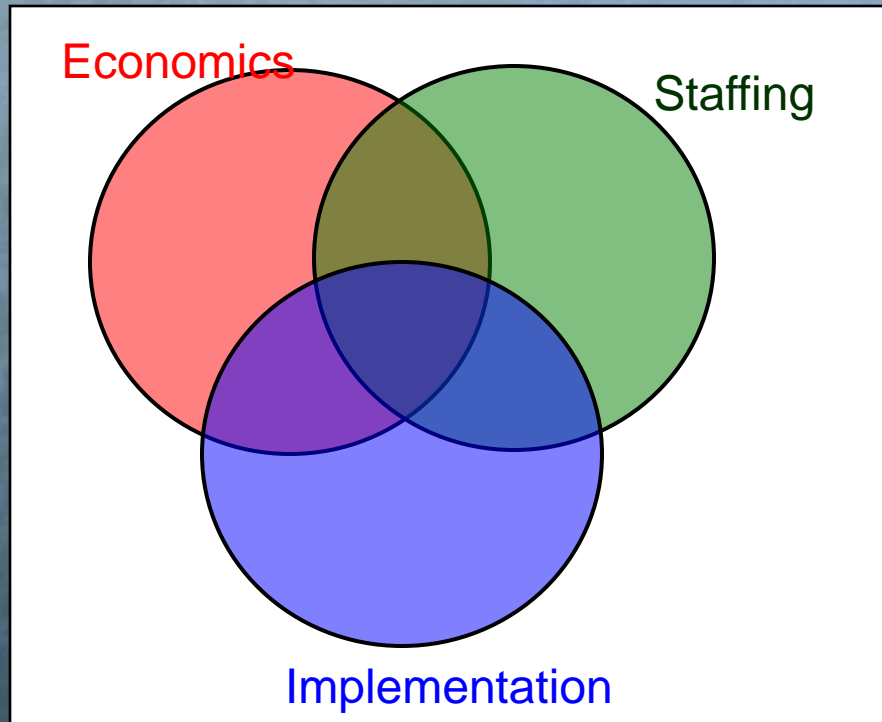
- Remote Sensing
- Wall-to-Wall Mapping
- Percent cover of indicator grasses

When to measure

- Surface Disturbance Annually
- Vegetation intra-annual

Requirement Considerations

The Manager Perspective



Economics

- Funds available from FO, AIM
- Identifying long-term funds
- Setting aside money for imagery

Staffing

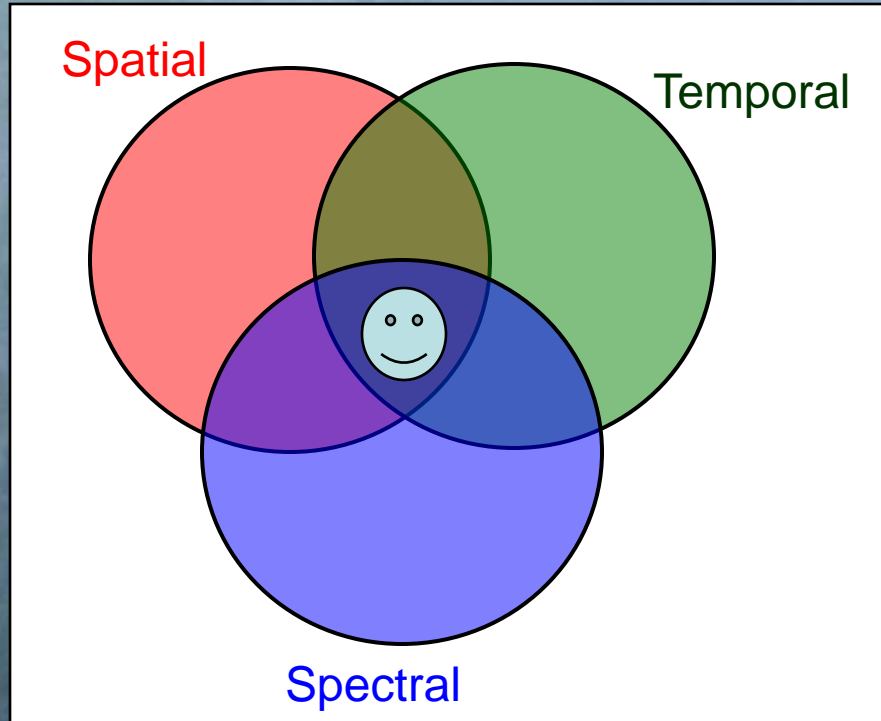
- One GIS Staff person (1 pending)
- In-house staff and partners for fieldwork
- Working with 3rd Party and NOC for plan development and training

Implementation

- Long-term Monitoring
- Tied to Plan Amendment

Requirement Considerations

The Remote Sensing Geek Perspective



Spatial

- Need to capture two-track roads
- Grasses and Shrubs

Temporal

- NAIP every 3 years
- RapidEye multiple times per year
- Capturing phenology of grasses is key

Spectral

- Vegetation requires infrared

Remote Sensing Systems

Domains:

Spatial:

0.5 m-5m

10-30m

100-500m

1k-8km

Temporal:

0.5 hr

Daily

Weekly

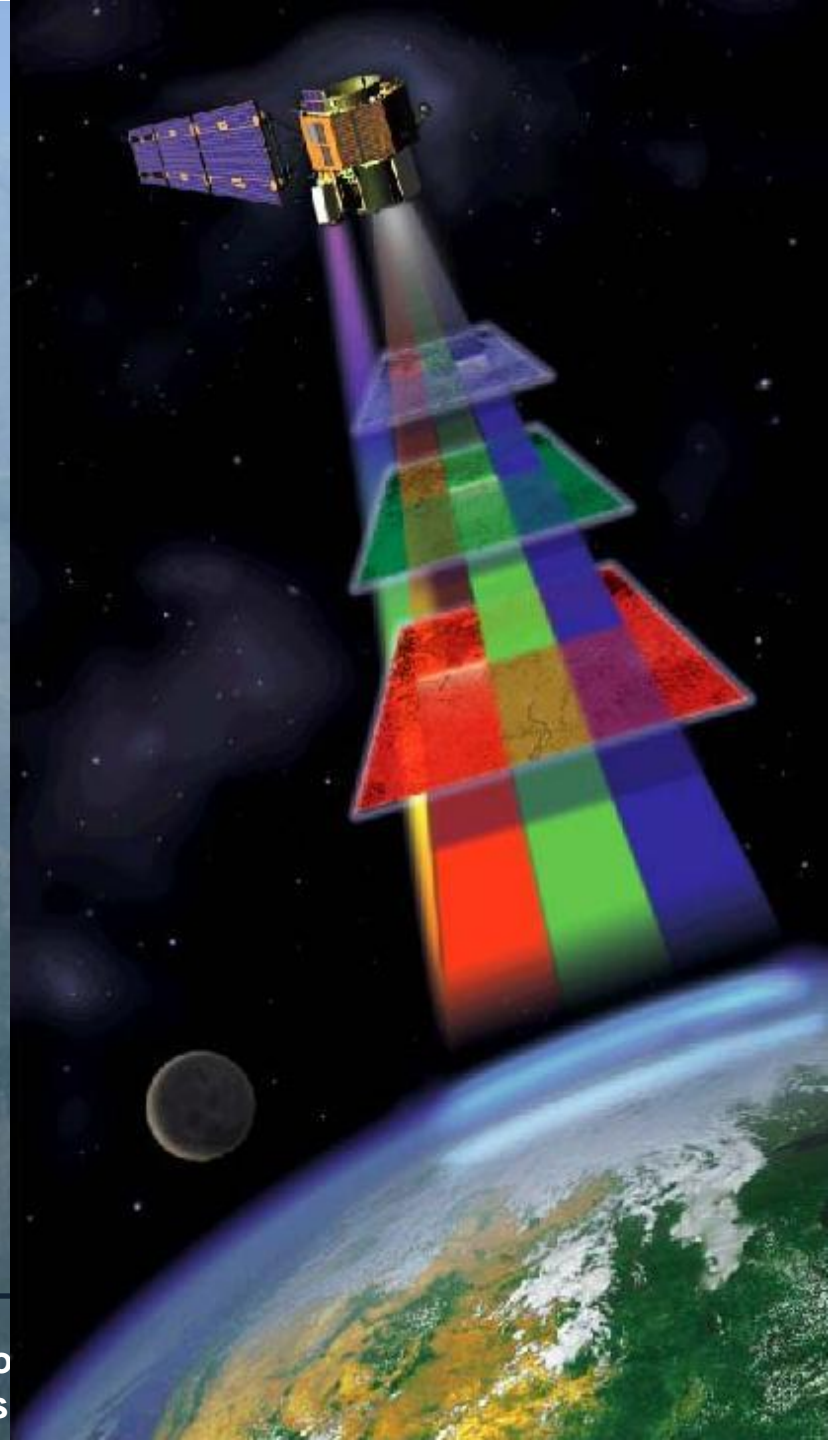
Bimonthly

Spectral:

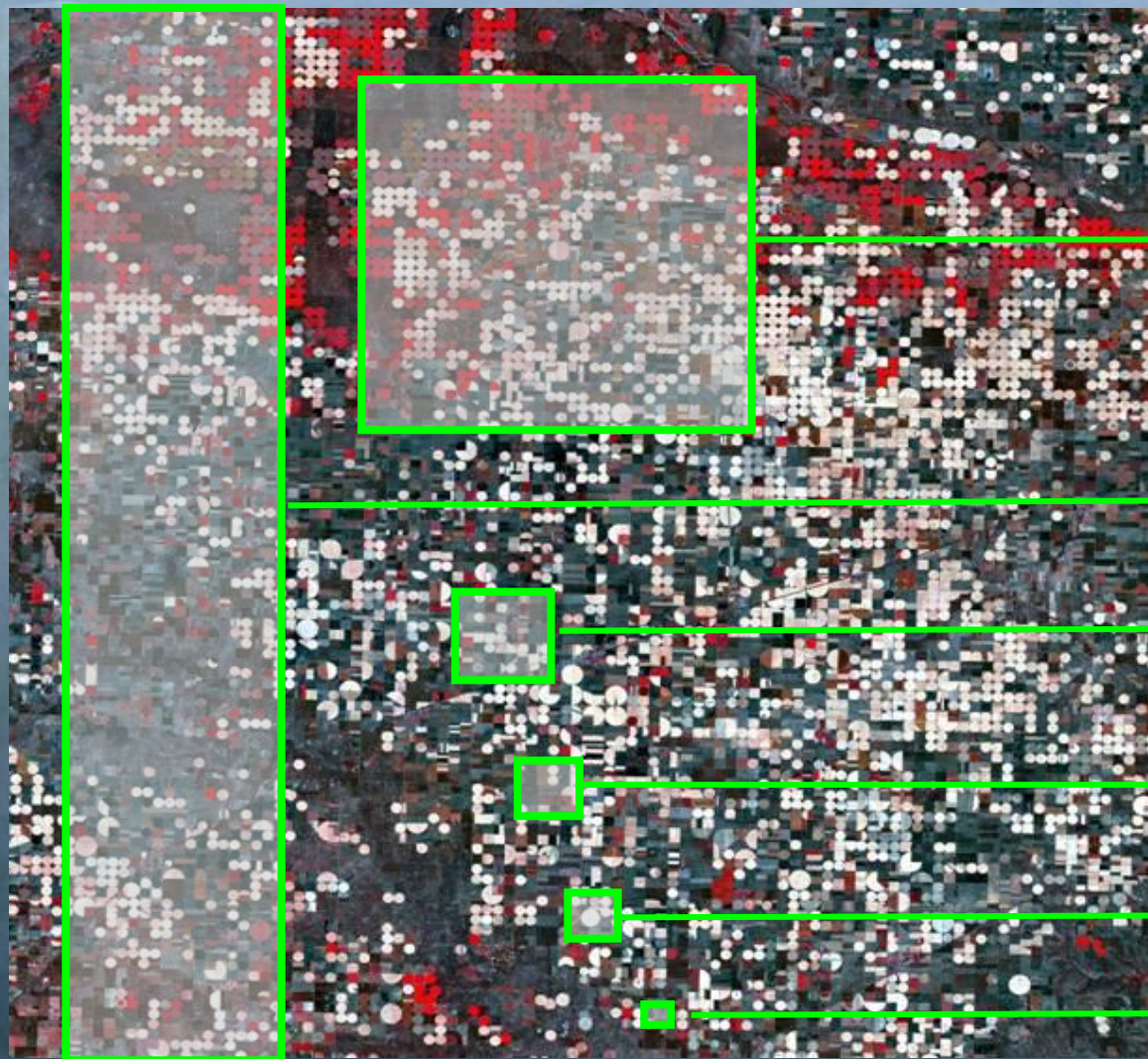
Panchromatic (1)

Multispectral (2-7)

Hyperspectral (10s-100s)



Imagery Comparisons



Landsat

**ASTER,
SPOT**

EO-1 ALI

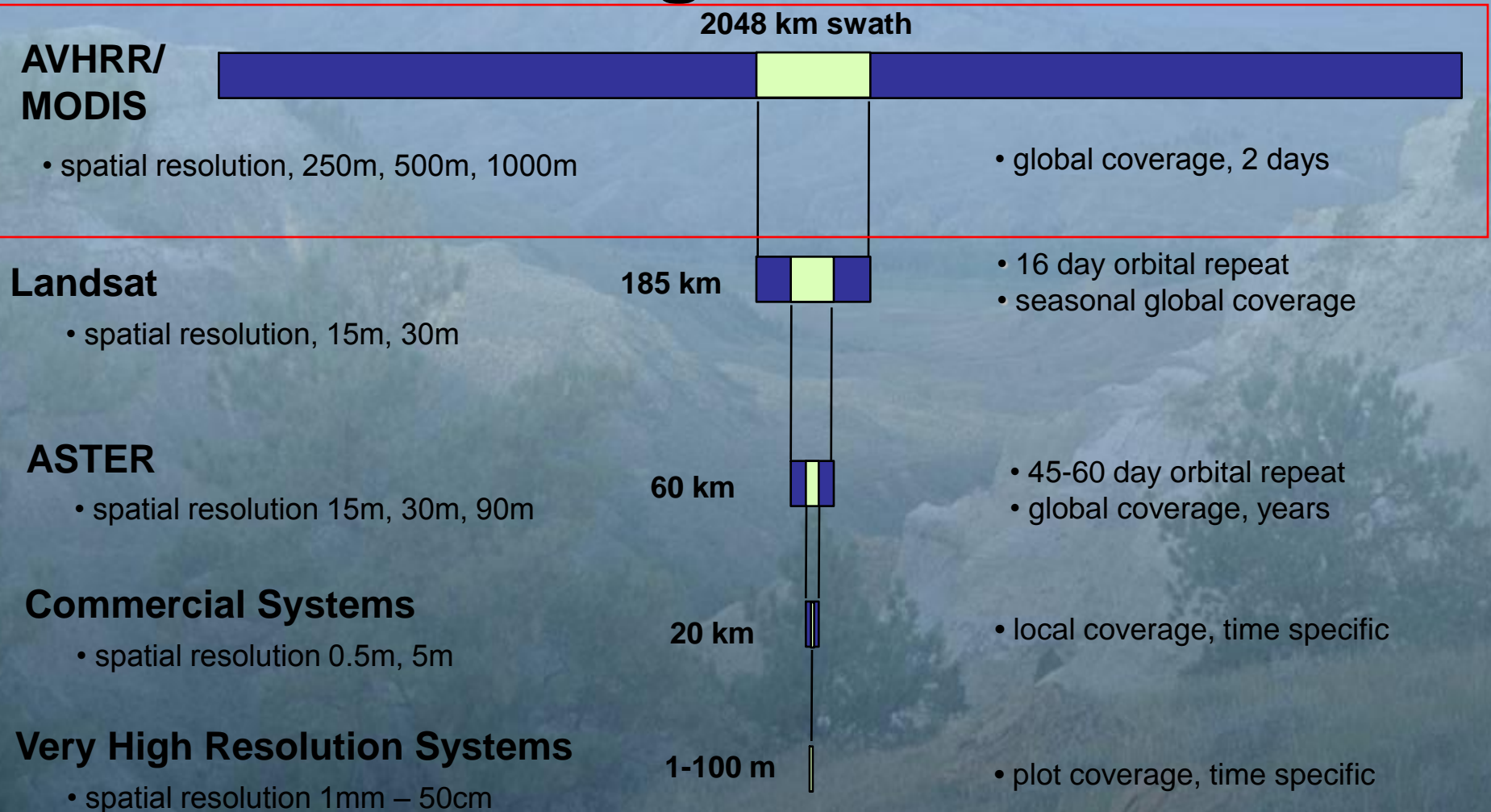
QuickBird

IKONOS

OrbView-3

Aerial

Remote Sensing Resolution



High Temporal Frequency Data



1989



1990



1991



1992



1993



1994



1995



1996



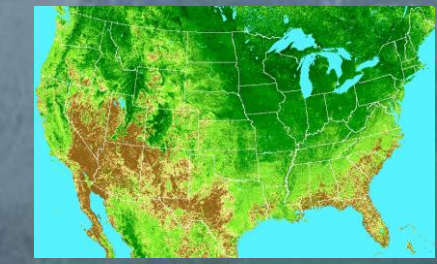
1997



1998



1999



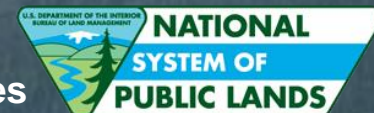
2000

Normalized Difference Vegetation Index = $\frac{NIR - Red}{NIR + Red}$



National Training Conference
March 2009

National Operations Center
Division of Resource Services

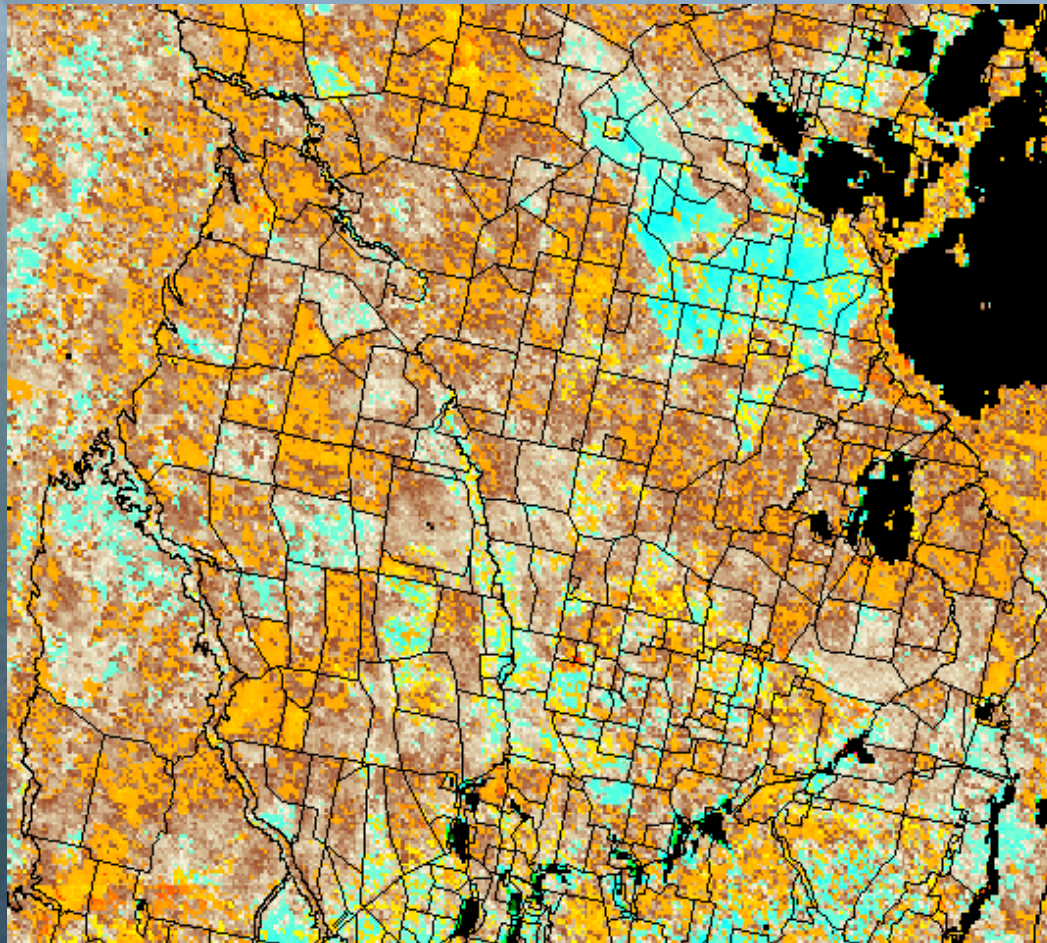


MODIS Landscape Performance

2007 Pre-Murphy Complex Fire



Over-Performing
Normal
Under-Performing



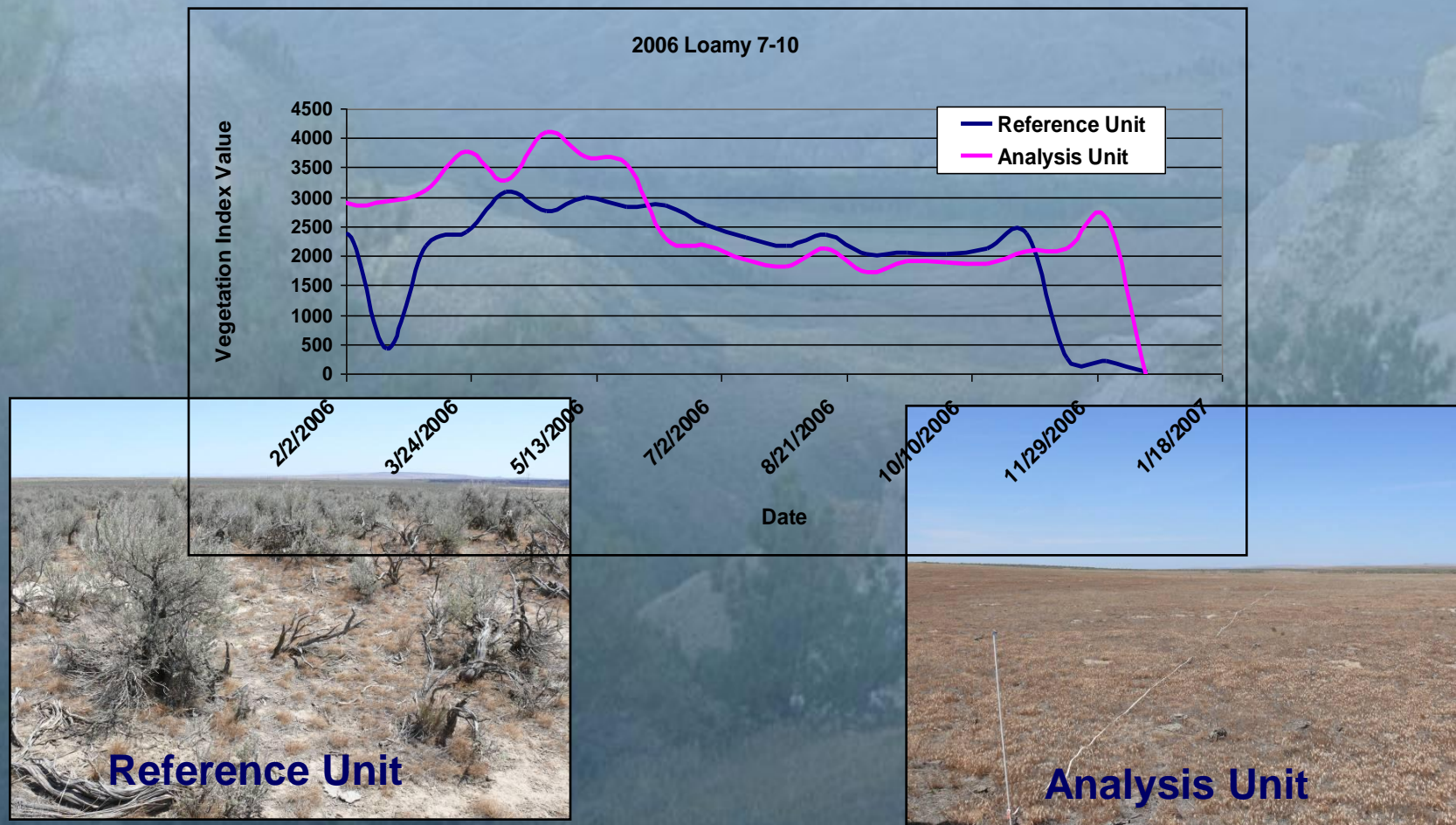
Anomalies in the Northeast Align with the Clover (7/15/05) and Sailor Cap (8/25/2006) Fires

Most anomalies align with fence lines



Phenological Signatures

Comparison Between Two Sites



Source: J. Tagestad – Pacific Northwest National Laboratory

Spectral Bands

- **Blue** 440 – 510 nm
- **Green** 520 – 590 nm
- **Red** 630 – 685 nm
- **Red Edge** 690 – 730 nm
- **NIR** 760 – 850 nm

Satellite Altitude

- 630 km

Camera Angle

- +/- 25 degrees

Pixel Size, (orthorectified)

- 5 m

Tile Size (scence)

- 25 x 25 km

Swath Width / Length

- 77 km x 1500 km

Revisit Time

- Daily

Equator Crossing Time

- 11:00 am

Image Capture Capacity

- 4 Million sq.km daily

Satellite Specifications

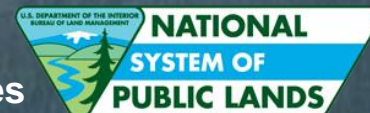
Price = ~\$1.25/km2



CAPABILITIES

**National Planning Conference
March 2009**

**National Operations Center
Division of Resource Services**



Remote Sensing Resolution

2048 km swath

AVHRR/ MODIS

- spatial resolution, 250m, 500m, 1000m

- global coverage, 2 days

Landsat

- spatial resolution, 15m, 30m

- 16 day orbital repeat
- seasonal global coverage

ASTER

- spatial resolution 15m, 30m, 90m

- 45-60 day orbital repeat
- global coverage, years

Commercial Systems

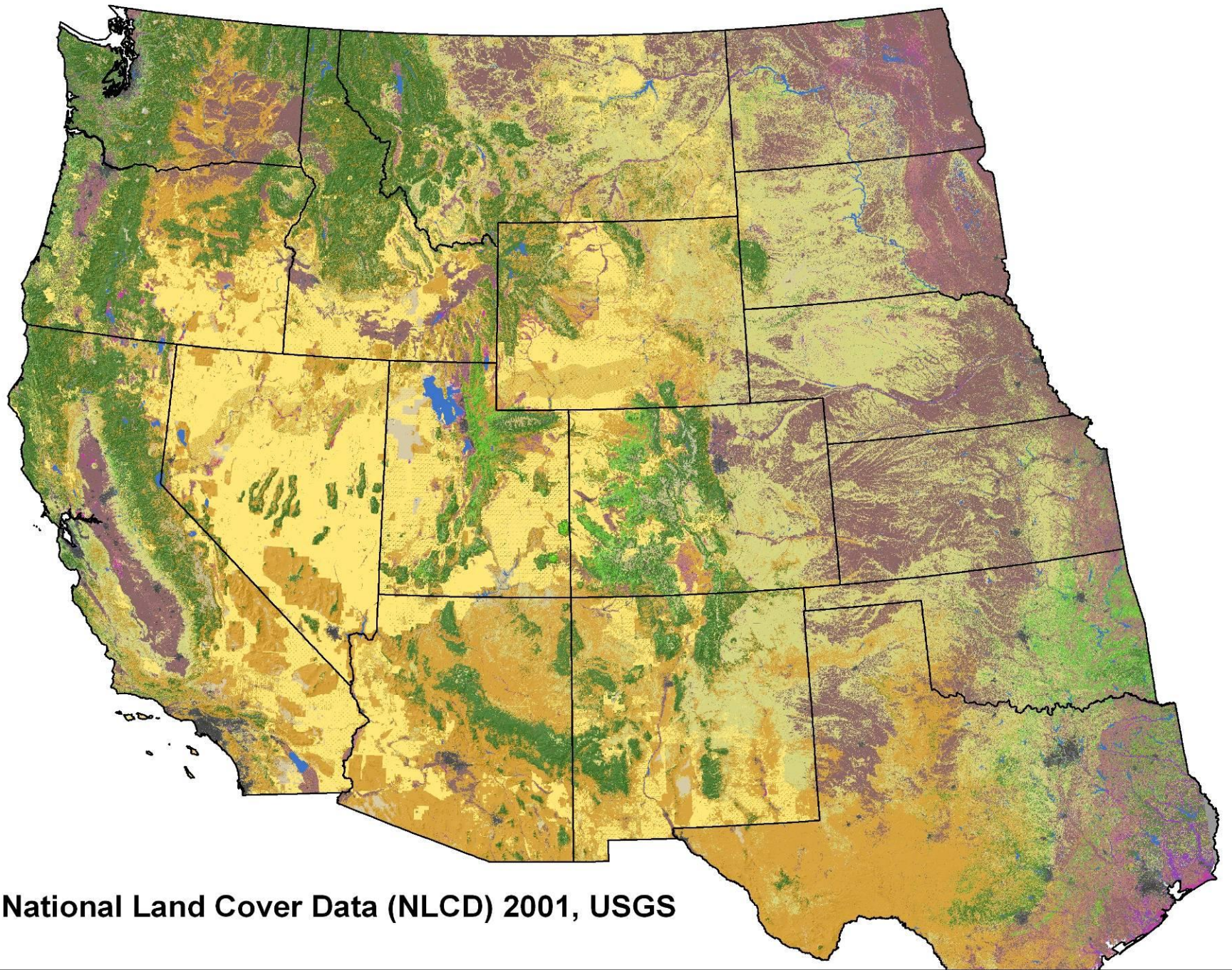
- spatial resolution 0.5m, 5m

- local coverage, time specific

Very High Resolution Systems

- spatial resolution 1mm – 50cm

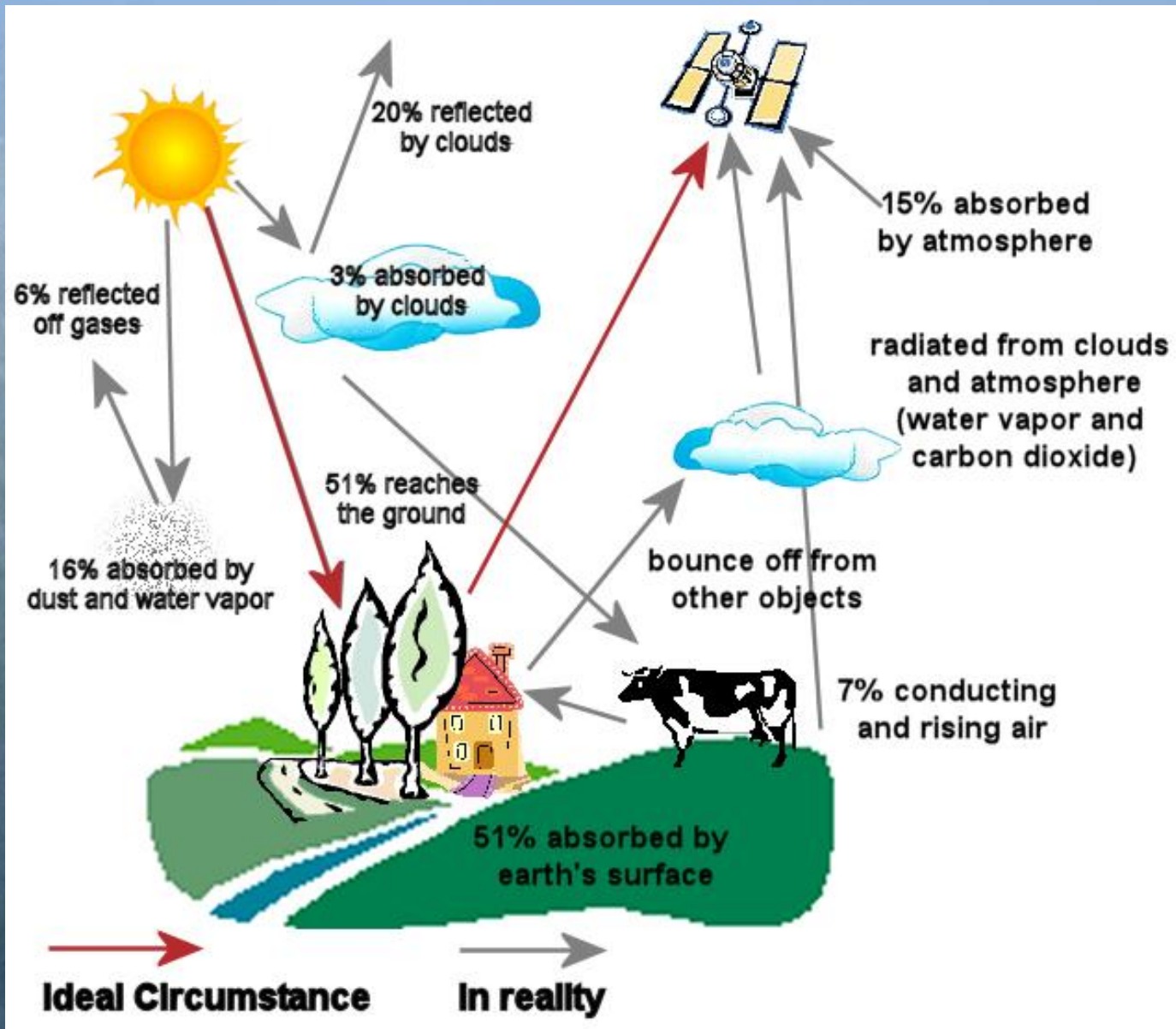
- plot coverage, time specific



National Land Cover Data (NLCD) 2001, USGS

Vegetation Datasets

- National Land Cover Dataset (NLCD)
 - www.mrlc.gov
 - Overall: 38-70% @ Anderson Lv 2
 - Anderson Lv 1 74-85%
- LANDFIRE
 - www.landfire.gov
 - Great Basin – 50% Overall; 67% using SAF/SRM
- ReGAP – Northwest & Southwest
- SAGEMAP
 - Combines a stitched product of multiple vegetation classification efforts



NLCD 2001 Land Cover Classes

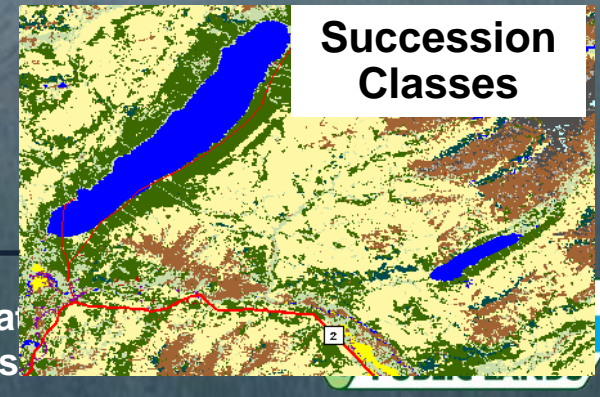
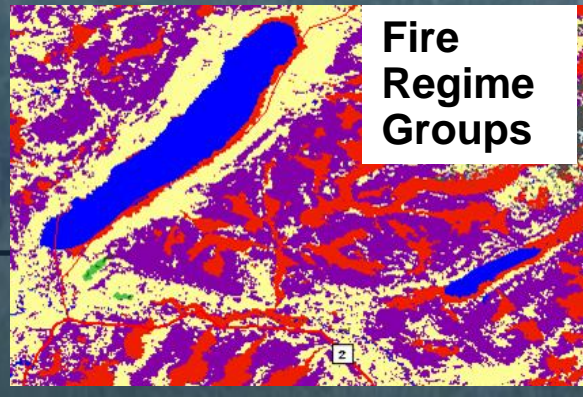
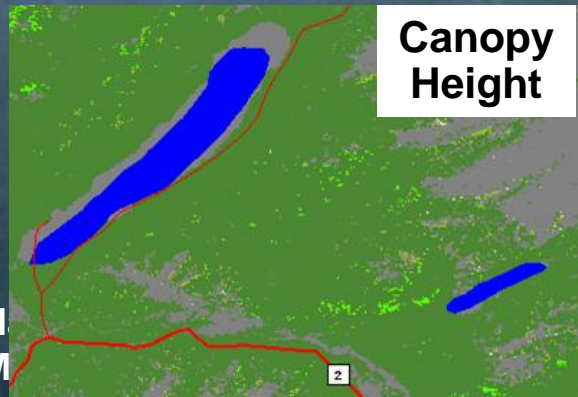
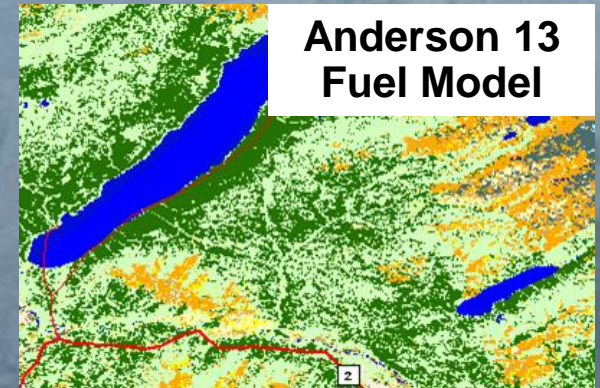
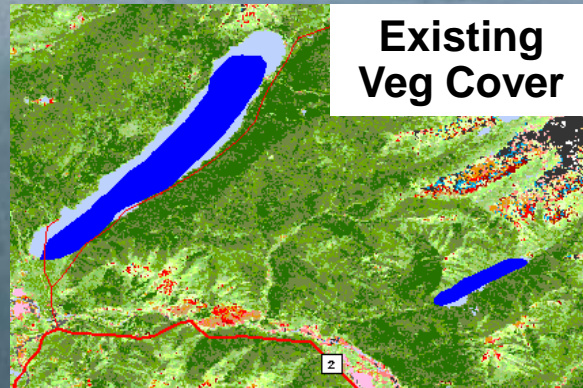
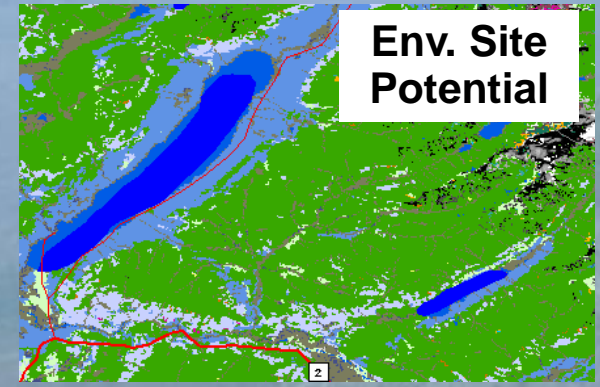
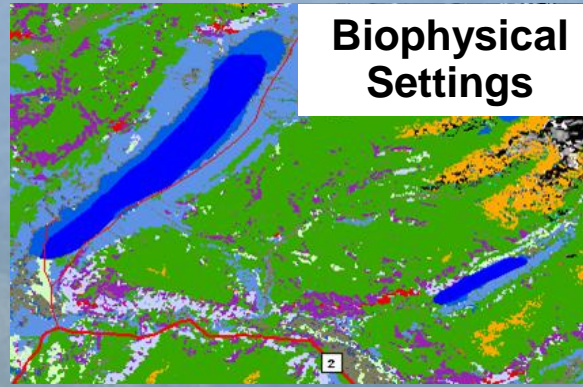
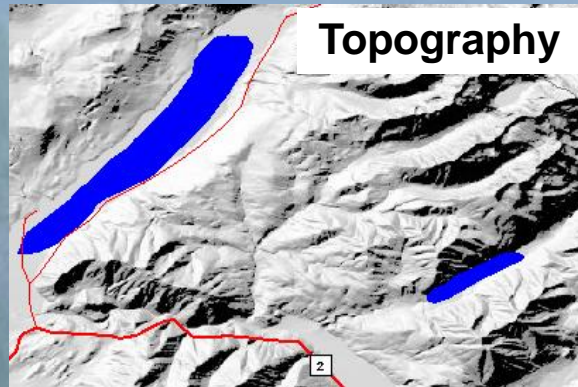
- Water
 - Open Water
 - Perennial Ice/Snow
- Developed
 - Developed, Open Space
 - Low Intensity
 - Medium Intensity
 - High Intensity
- Forests
 - Deciduous
 - Evergreen
 - Mixed
- Barren(Rock/Sand/Clay)
- Non-Vascular
 - Lichens*
 - Moss*
- Shrubland
 - Dwarf Shrub*
 - Shrub
- Grasslands/Herbaceous
 - Herbaceous
 - Sedge Herbaceous*
- Agriculture
 - Pasture/Hay
 - Cultivated Crops
- Wetlands
 - Woody Wetlands
 - Emergent Herbaceous Wetlands

* Alaska only

What is LANDFIRE?

- National Effort/Multi-Agency
- Primary Focus: Develop consistent fuels and vegetation data across the nation
- Uses data from MRLC
 - Landsat-based
- Not intended for local level analysis
- Develop nationally consistent 30m map data of vegetation, wildland fuels, and ecosystem fire regime conditions

LANDFIRE – Products



LANDFIRE Vegetation Classification System: Ecological Systems

Ecological Systems: an additional floristic level in the US-NVC hierarchy

Formation Class

Woodland

Formation Subclass

Evergreen Woodland

Formation Group

Temperate or Subpolar needle-leaved...

Formation Subgroup

Natural vs. Cultural

Formation

Rounded-crowned...

Ecological Systems

Alliance

Pinus palustris / *Quercus* spp. Woodland Alliance

Association

Pinus palustris - *Pinus taeda* / *Quercus geminata* -
Quercus hemisphaerica - *Osmanthus americanus*
var. *americanus* / *Aristida stricta* Woodland

LANDFIRE Vegetation Classification System

NatureServe's Ecological Systems

Designed for mid-scale mapping of existing vegetation

Nationally consistent and can be applied nationwide

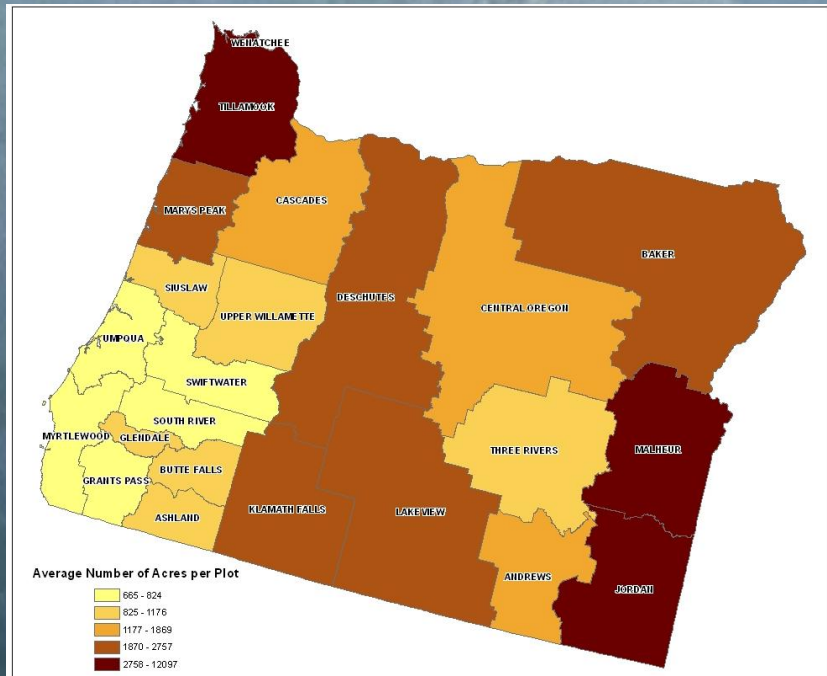
Provided a template which could be adapted to for mapping potential vegetation

Links to National Vegetation Classification System



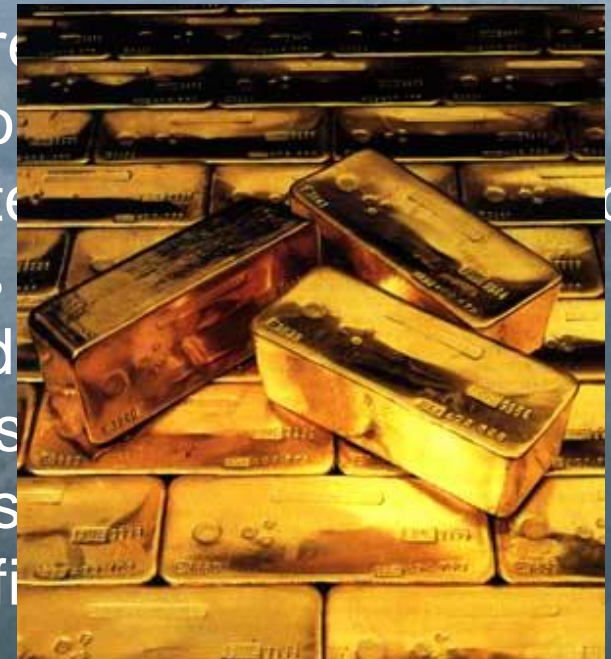
LANDFIRE Accuracy

Super Zone	Ecological System Agreement (%)	# of EVT Classes	Similarity Class Agreement (%)	# of EVT Similarity Classes Assessed	SAF/SRM Agreement (%)	# of SAF/SRM Classes Assessed
Great Basin	50	56	63	22	67	36



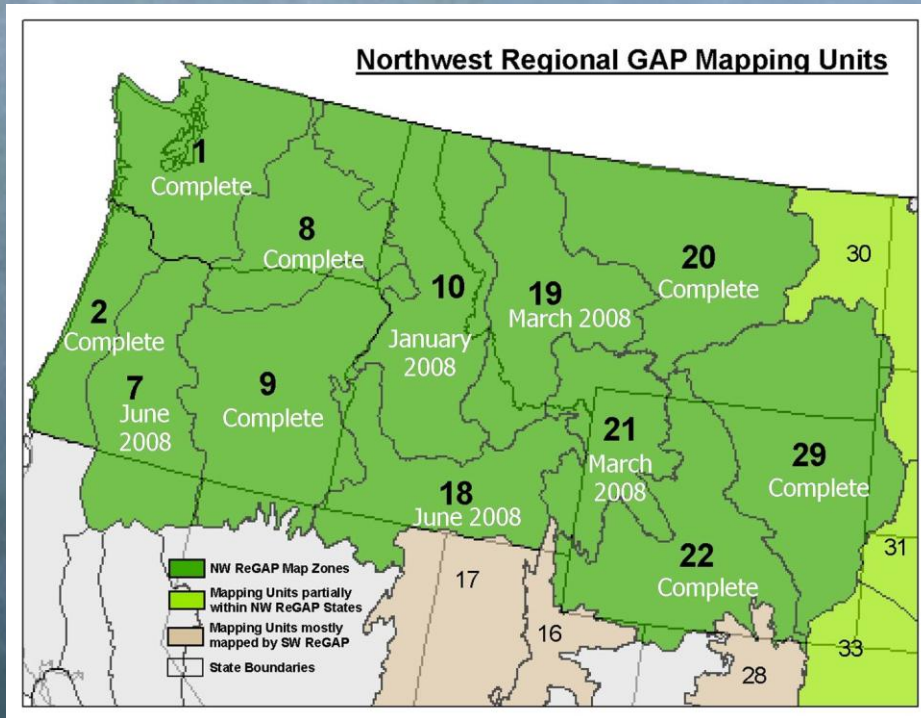
Remote Sensing and Fieldwork

- Not a replacement for fieldwork
- Remote sensing data is not perfect
- Extends the reach of fieldwork
- Increases the accuracy of fieldwork
- Access to data is improved
- Good for monitoring change over time



ReGap

Northwest



Southwest



<http://gapanalysis.nbii.gov/portal/server.pt>

Use the Best Information Available...

Idaho BLM Land Cover Data Standard


- Develop Idaho BLM land cover classification system consistent with NVCS
- Provide a glossary of terms.
- Define mapping standards for RMPs consistent with national standards.
 - Accuracy, minimum map units, etc.
- Provide directions for land cover classification use for RMPs.
 - Define appropriate classification thematic scale for RMP map.
 - Explain how to handle “special” fine-scale vegetation communities (e.g., aspen communities).

Why develop a standard?

- Communication: internal and external
- Inventory: point-in-time description
- Monitoring: measuring changes over time
- Aggregating information across admin. boundaries



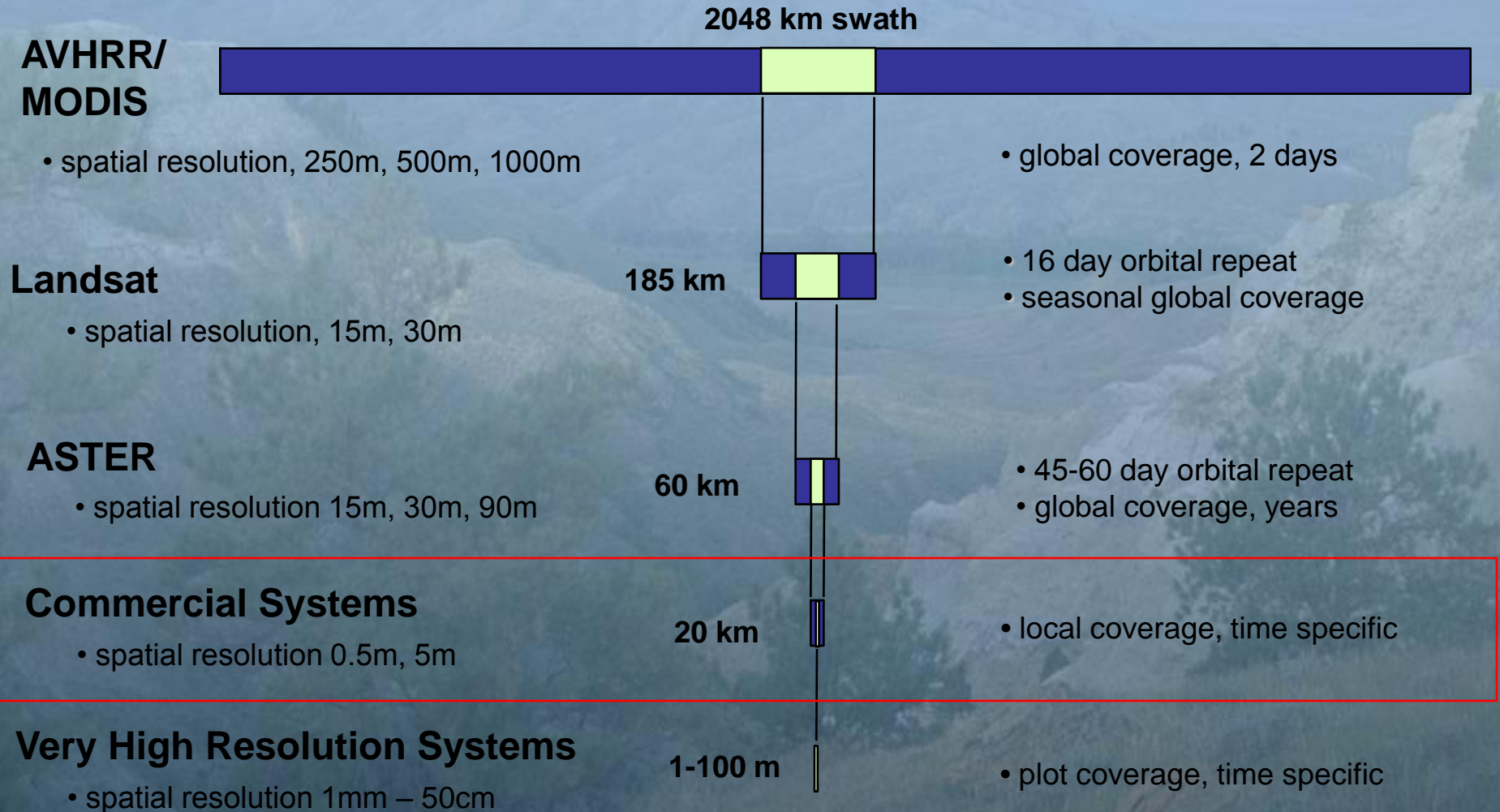
Idaho BLM Land Cover Classification Scheme

Scale	Planning Use	Idaho BLM Land Cover Categories
Broad-Scale  Fine Scale	State-wide Plans	Group
	State-wide Plans / RMP	Class
	RMP	Division
	RMP / Activity Plans / Project Plans	Sub-Division
	Activity Plans / Project Plans	Ecological System
	Project Plans	Alliance
	Site Plans	Association

More than one way to skin a cat...
mapping vegetation isn't just about classification.

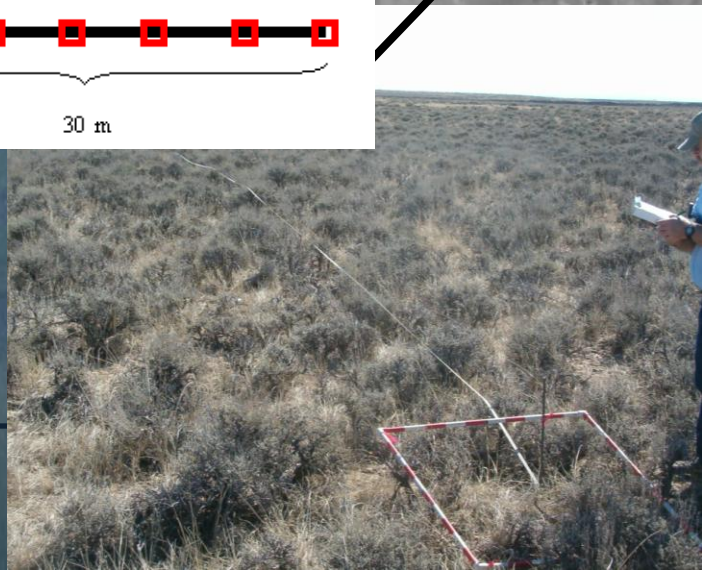
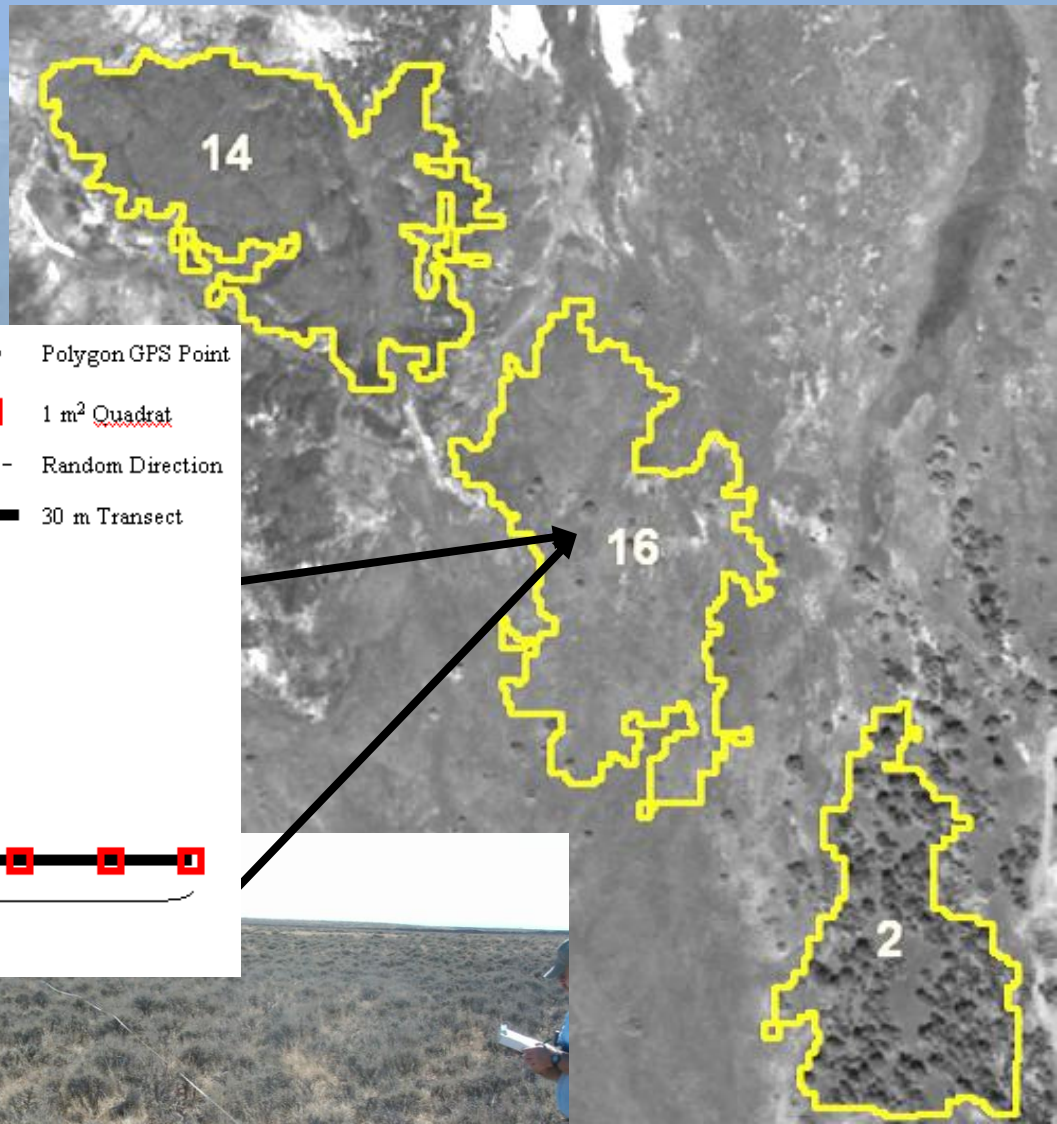
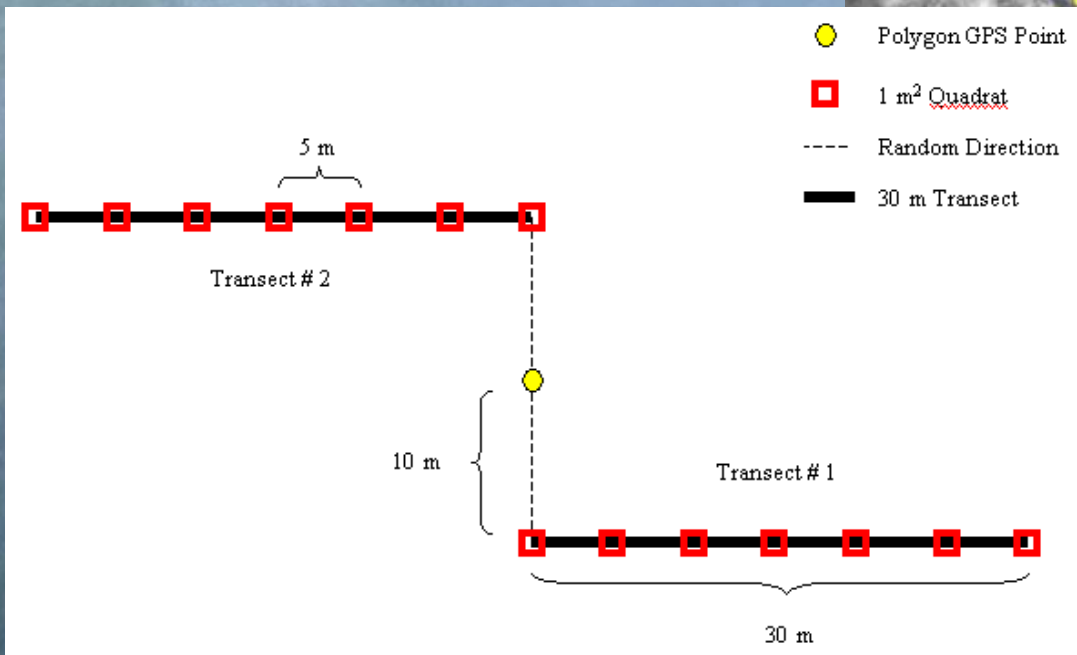


Remote Sensing Resolution



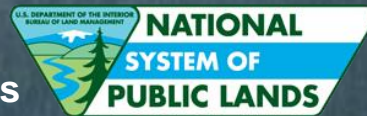
Continuous Field Mapping (CFM)

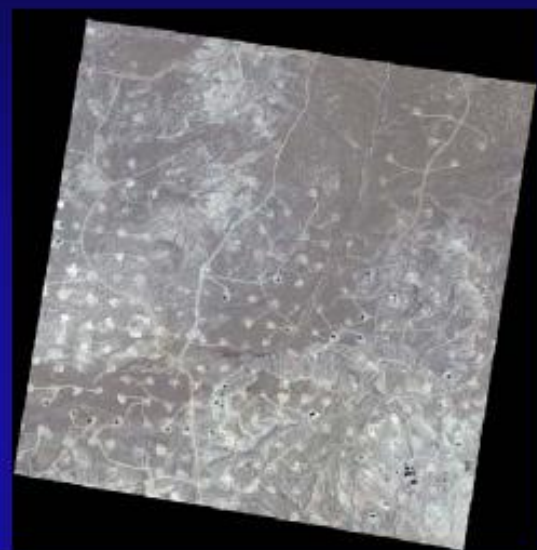
- Variation on the traditional classification mapping typically done using remote sensing data.
- Mapping variables based on their percent cover.
- Enables the ability to monitor within class vegetative changes.
 - Percent shrub, bare ground, litter, herbaceous, etc.
- Multi-scale by design



National Planning Conference
March 2009

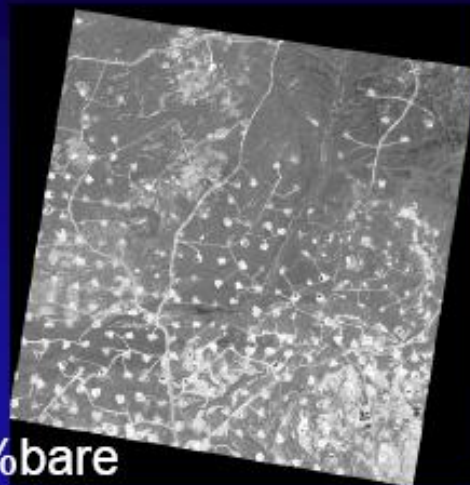
Water
Services



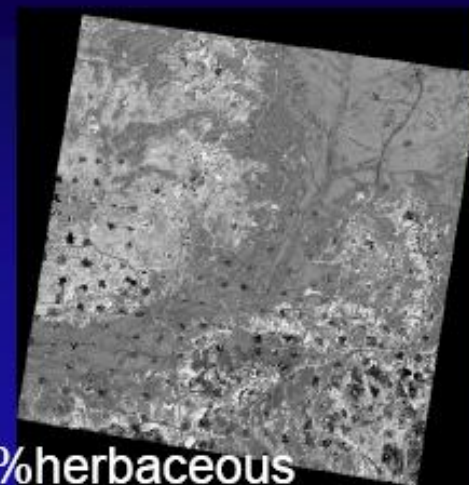


2.4m R-G-B-Nir
Quickbird Scene

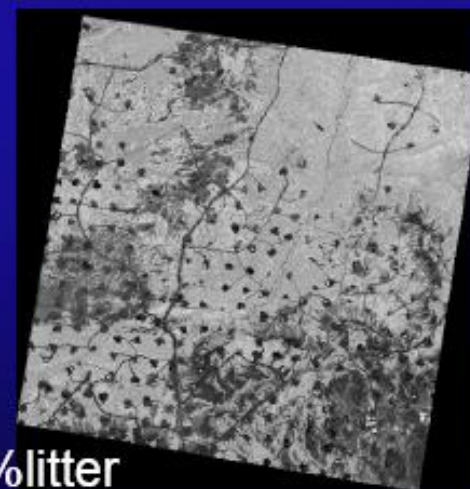
%bare



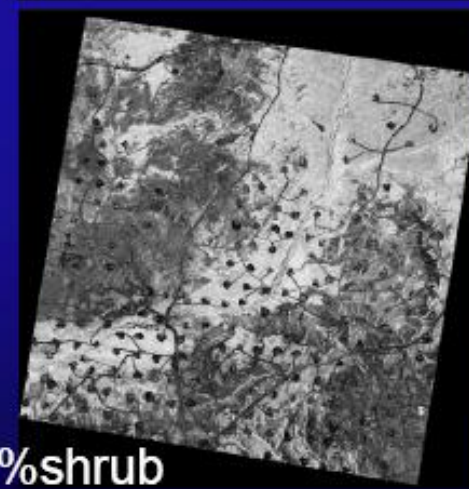
%herbaceous



%litter



%shrub

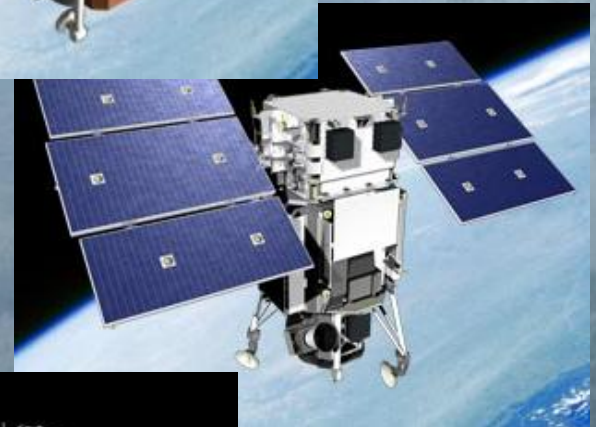


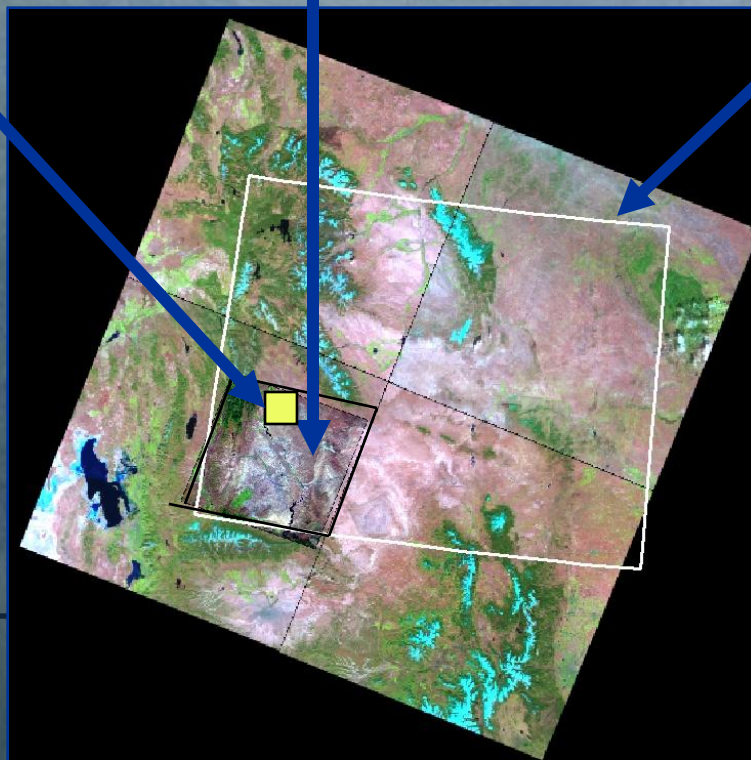
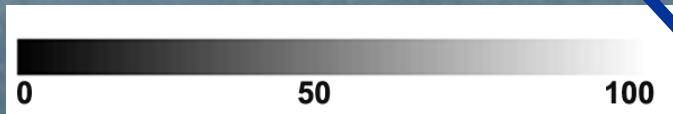
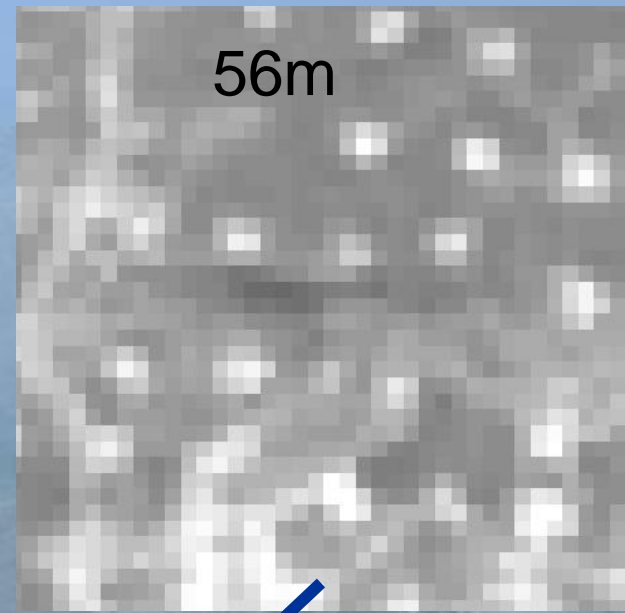
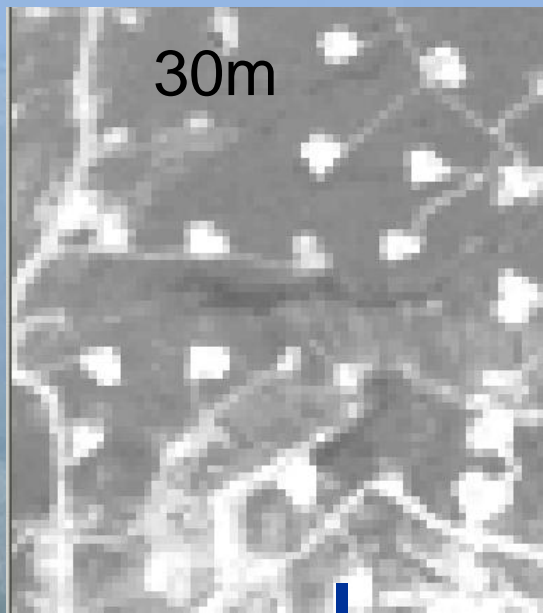
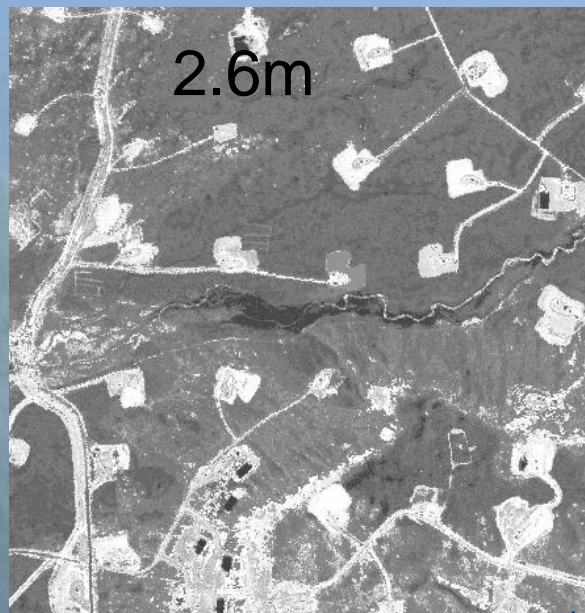
Prediction accuracies at The Quickbird scale

Sensor	Variable	Model R	N	R	R ²	RMSE
Quickbird	sage	0.90	61	0.92	0.85	2.99
Quickbird	shrub	0.89	61	0.91	0.82	2.95
Quickbird	bare	0.91	61	0.94	0.89	6.38
Quickbird	herbaceous	0.80	61	0.88	0.77	5.02
Quickbird	litter	0.86	61	0.90	0.82	4.36
Quickbird	big sage	0.89	61	0.9	0.84	3.04
Quickbird	wyomingensis	0.85	61	0.9	0.75	3.71
Quickbird	b. shrub	0.85	61	0.9	0.79	5.07

Digital Globe

- Quickbird (2001)
 - 60 cm Pan; 2.4 m Multispectral (VISNIR)
 - 4 Bands
 - 23 m CE90
- WorldView-1 (2008)
 - 50 cm Pan
 - Stereo Capability
 - 6.5 m CE90
- WorldView-2 (2009)
 - 46 cm Pan; 1.8 m Multispectral
 - 8 Bands
 - 12 m CE90
- Cost = ~25/km²





Percent Bare Ground
estimate @ 3 scales



Billings Field Office

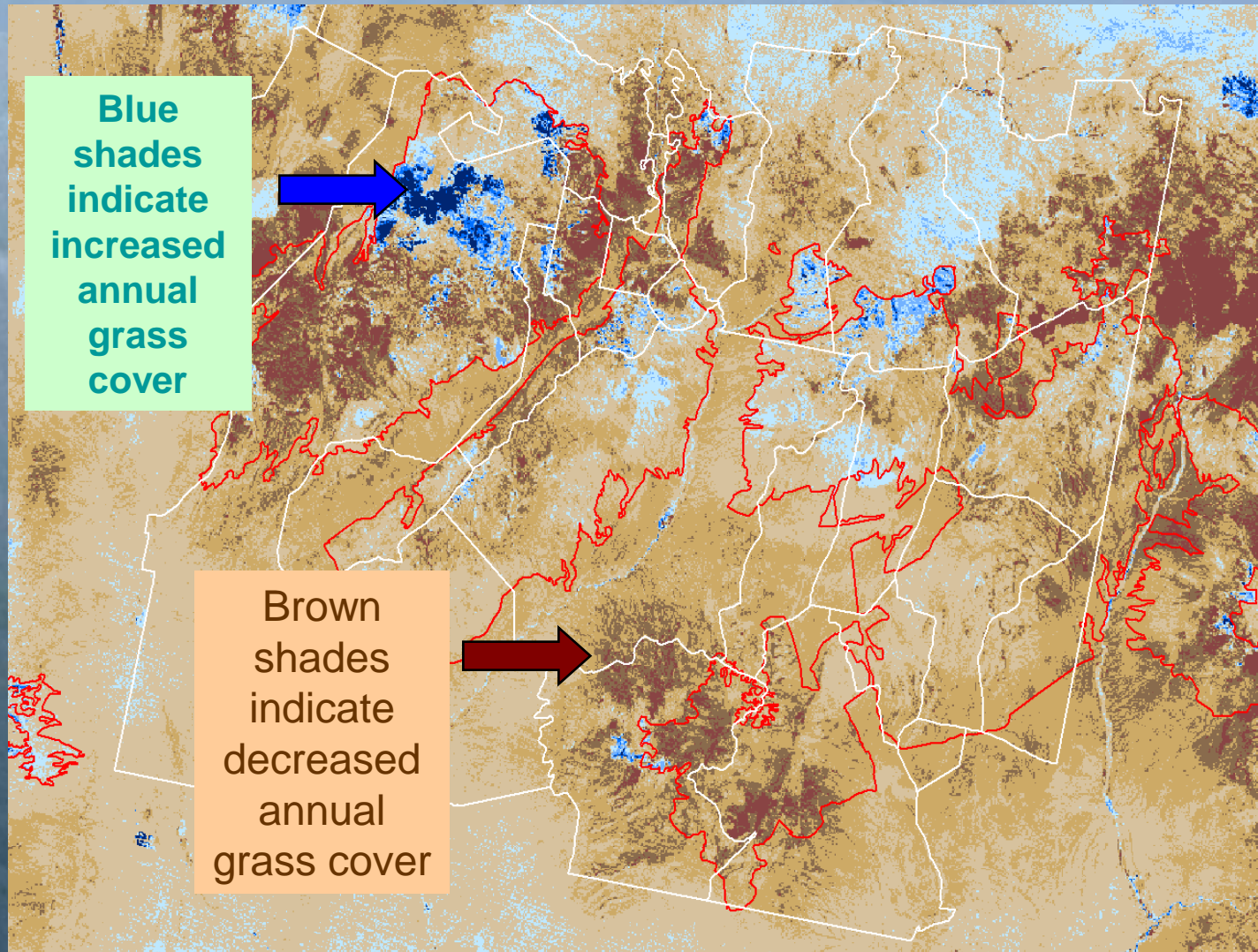
- In the midst of their RMP
- Contracted with USGS to develop CFMs for majority of planning area
- Will use to provide baseline vegetation data
- Primarily intended as a monitoring tool – process will be repeated periodically to provide data for quantifying if vegetation goals are being met.

Effectiveness of Treatments

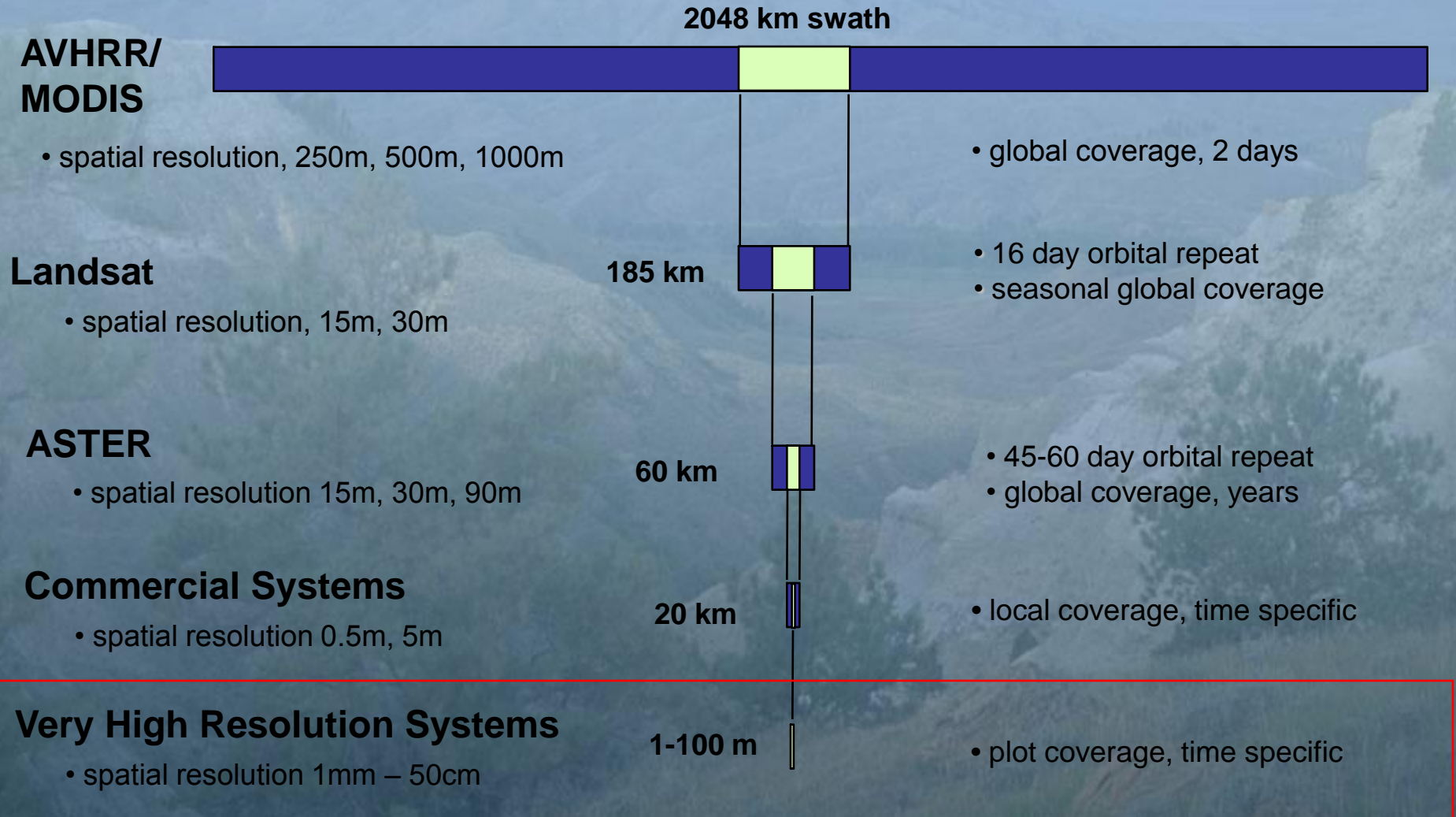
- Map past treatments (i.e. prescribed fire, seeding)
- Cumulative effect of disturbance (i.e. invasives, fragmentation)
- Cumulative effect of treatments (i.e. connectivity, fire regime)



Detecting Annual Grasses



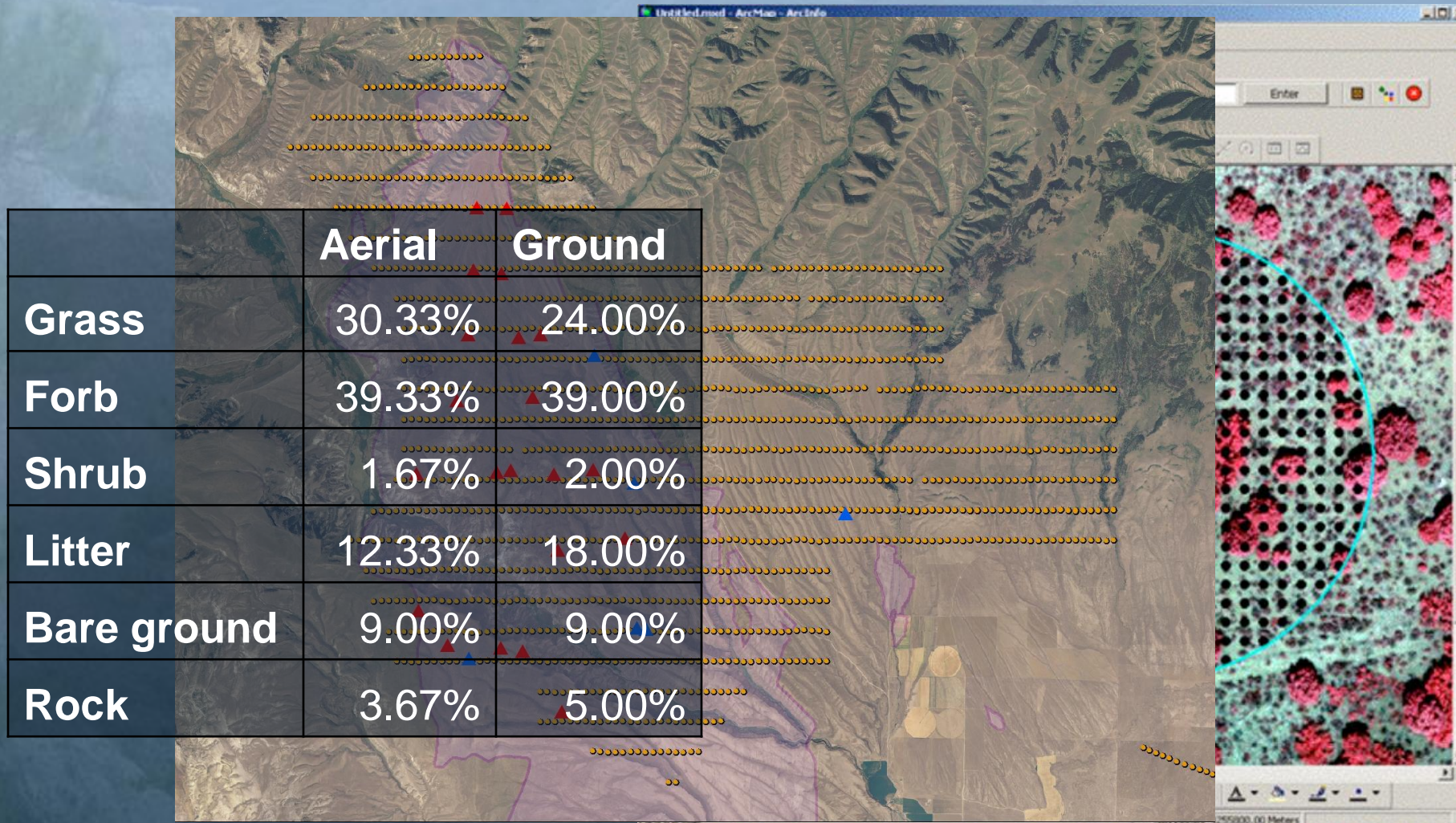
Remote Sensing Resolution



VLSA for Natural Resource Management



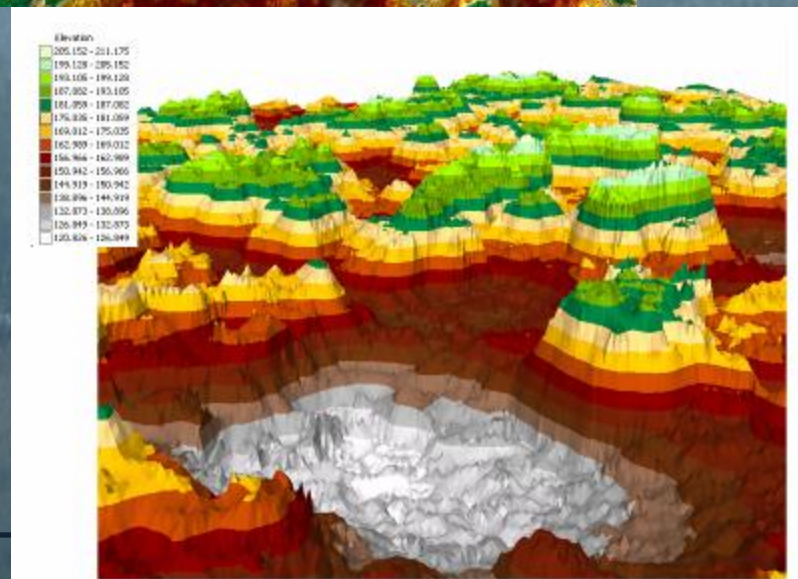
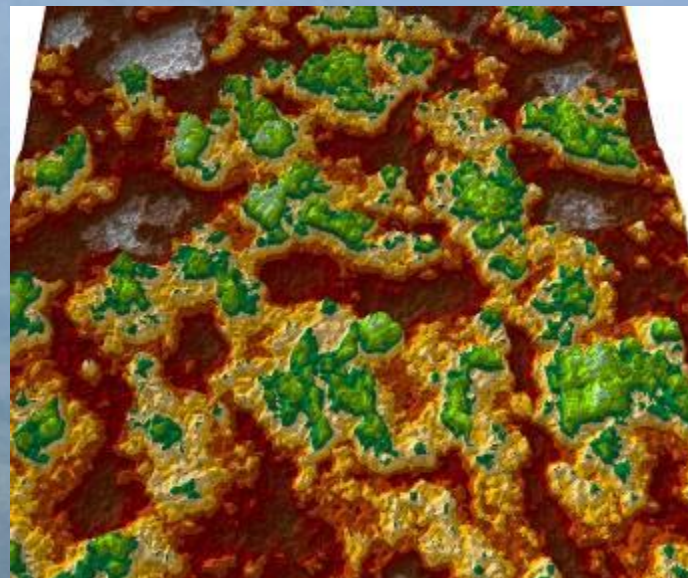
Remote Sensing as Sampling



Cost Comparison:

- Traditional Monitoring
 - 27 plots in 50,000 acre project area (Medicine Lodge)
 - Most allotments have 1 study plot per pasture
 - 2-3 plots per day
 - 4 hours per plot site including travel time and post processing
 - Typically 15 – 20 sites visited yearly
 - \$74.80 / site (GS-8, monitoring tech)
- Aerial Monitoring
 - One time funded monitoring project (Medicine Lodge) – \$25K
 - 1500 (3000 photos) photographic locations per 50,000 Acres
 - Flight Time = 6 hours
 - Analysis using existing software and verified with traditional data
 - \$16.67 / site (preflight planning, flight, post processing, travel and per diem)
 - UAV purchase (50,000 acres/year with 3000 photo locations)
 - 1st Year: \$4.87 / site (\$12,000 plus ½ WM preflight planning, flight, post processing)
 - 2nd Year: \$2.87 / site (\$6,000 plus ½ WM preflight planning, flight, post processing)
 - 3rd Year: \$1.87 / site (\$3,000 plus ½ WM preflight planning, flight, post processing)

Soil Monitoring



Powder River Basin Remote Sensing

- Multi-Agency effort to study the impacts of Coalbed Methane Development on the aquatic/riparian habitats
- Quantify in-stream habitats
 - Mapping verses Sampling
- Monitor in-stream habitats under different flow rates
 - Intra-annual and Inter-annual
- Derived measurements of channel properties
- Map riparian vegetation and invasive species
- Test new methods for developing stereo models from Very Large Scale Aerial (VLSA) photography



Derived Data

1. Vegetation Heights
2. Bank Erosion, Slope
3. Water Depth (need baseline of empty stream channel elevation)
4. Vegetative cover/Bare Ground

Uses

1. Training coarser resolution imagery
2. Monitoring invasive species
3. Change detection
4. Guide sampling
5. Visualization tool

Need

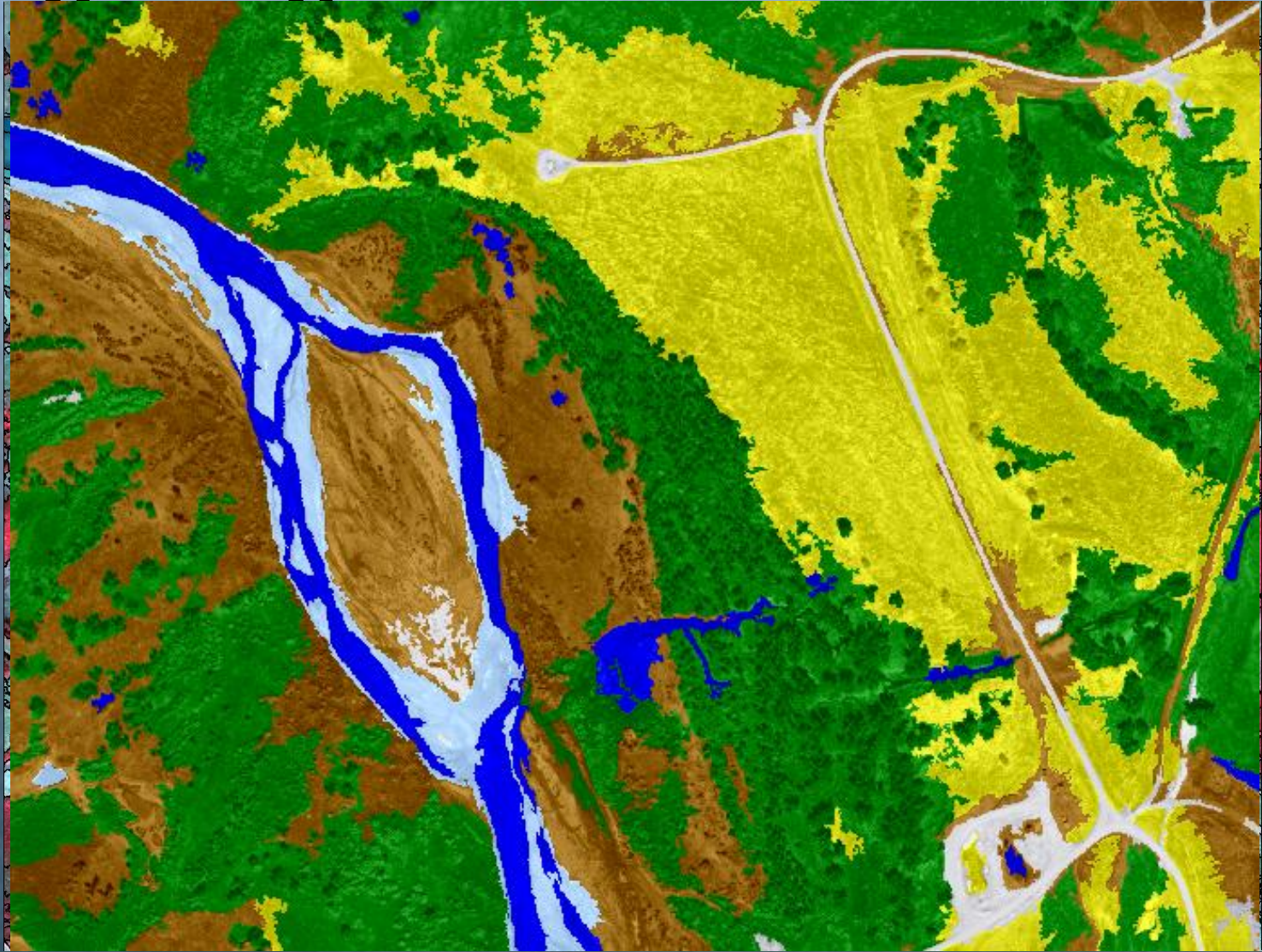
Accurate, Low-cost, multi-temporal, co-registered imagery

Some Available Resources

IP Software Tools

- Imagine 9.1 Available; 9.2 in testing
- Feature Analyst 4.1 (4 ArcGIS; 1 Imagine)
- Image Analysis for ArcGIS 9.2
- ENVI 4.5 (2 licenses)
- Definiens Developer 7 (1 license)
- Image Server
- Leica Photogrammetry Suite 9.2
- Stereo Analyst for ArcGIS 9.2 in testing
- ILMNIRM3AP9

Image Segmentation

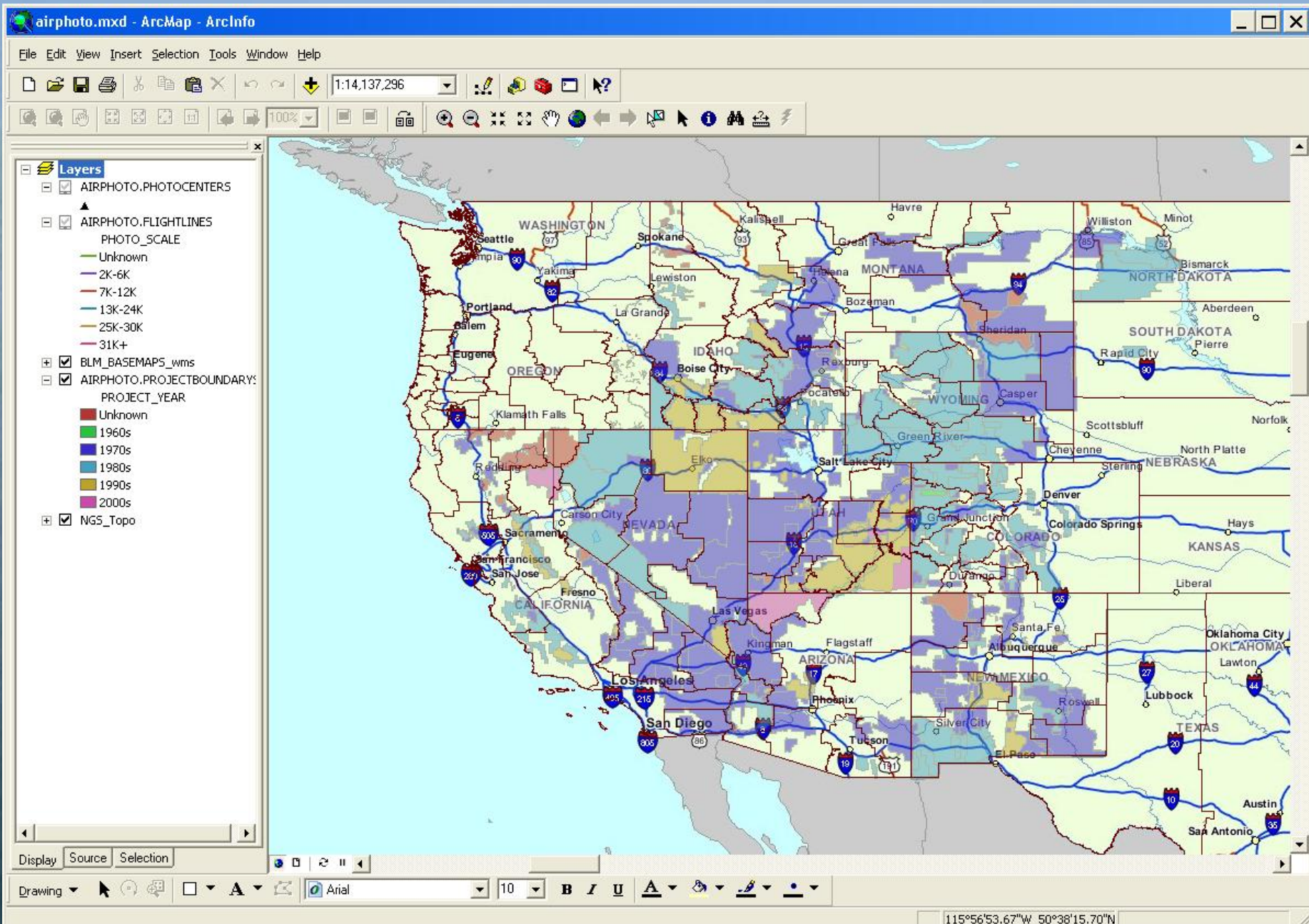


Remote Sensing Applications Center (RSAC)

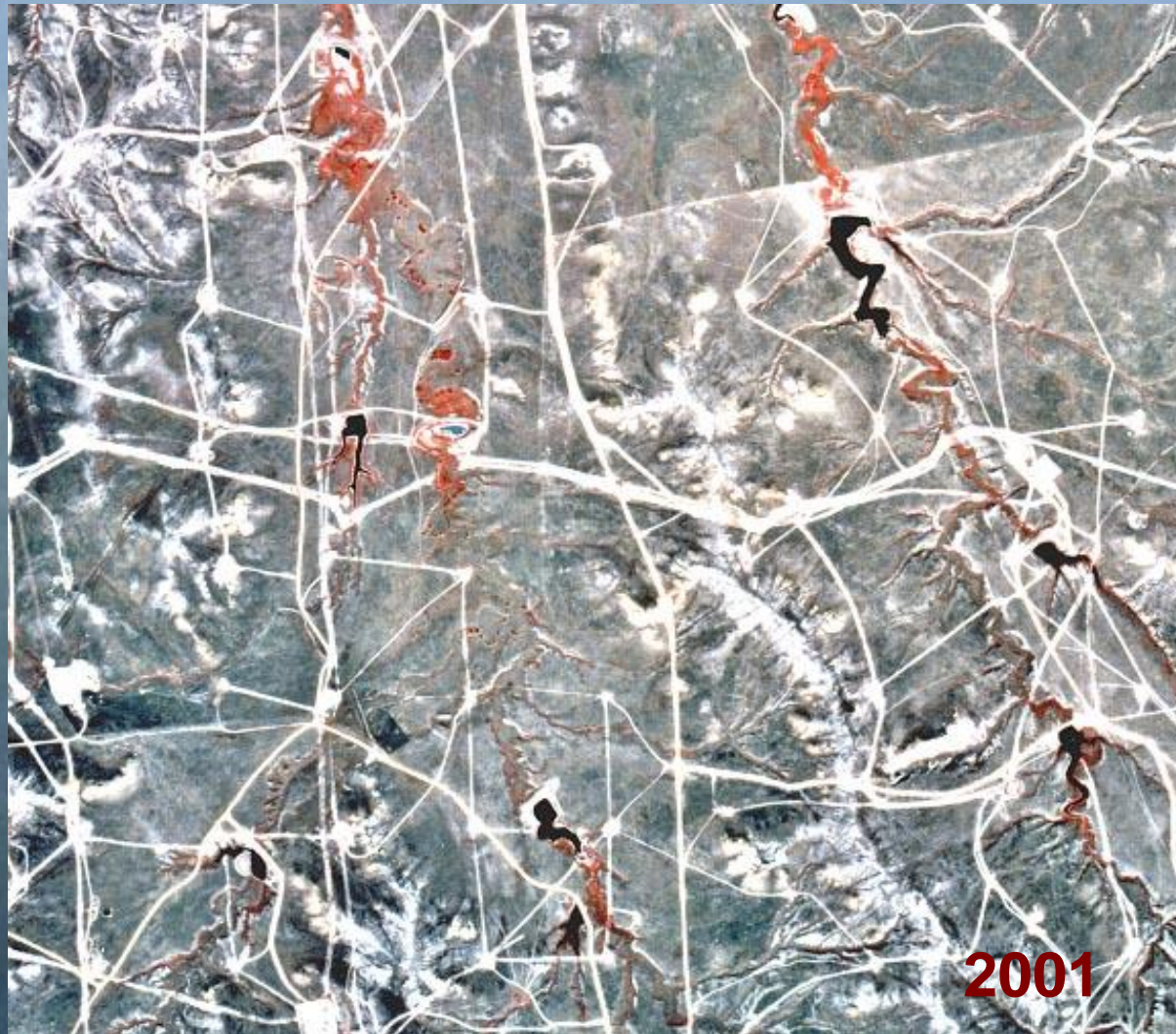
- US Forest Service Research Center
- <http://fsweb.rsac.fs.fed.us/>
- Great resource for remote sensing information
- Seamless 1-meter orthophotography for the US
- Requires client installed in ArcMap
- 166.2.126.235

Aerial Photography Spatial Index (APSI)

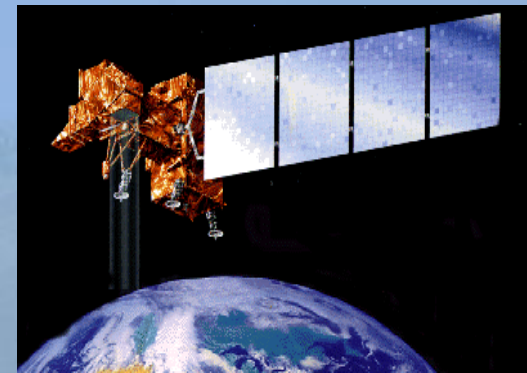
- Citrix Application – Need to be added to permissions list
 - <https://citrixnr.blm.doi.net>.
- ArcMap document to search for historical aerial photography collected by the BLM
- Approximately 600,000 frames
- Public Access: GeoCommunicator
- Internal: Translated into ArcGIS Server



Our Changing Landscape



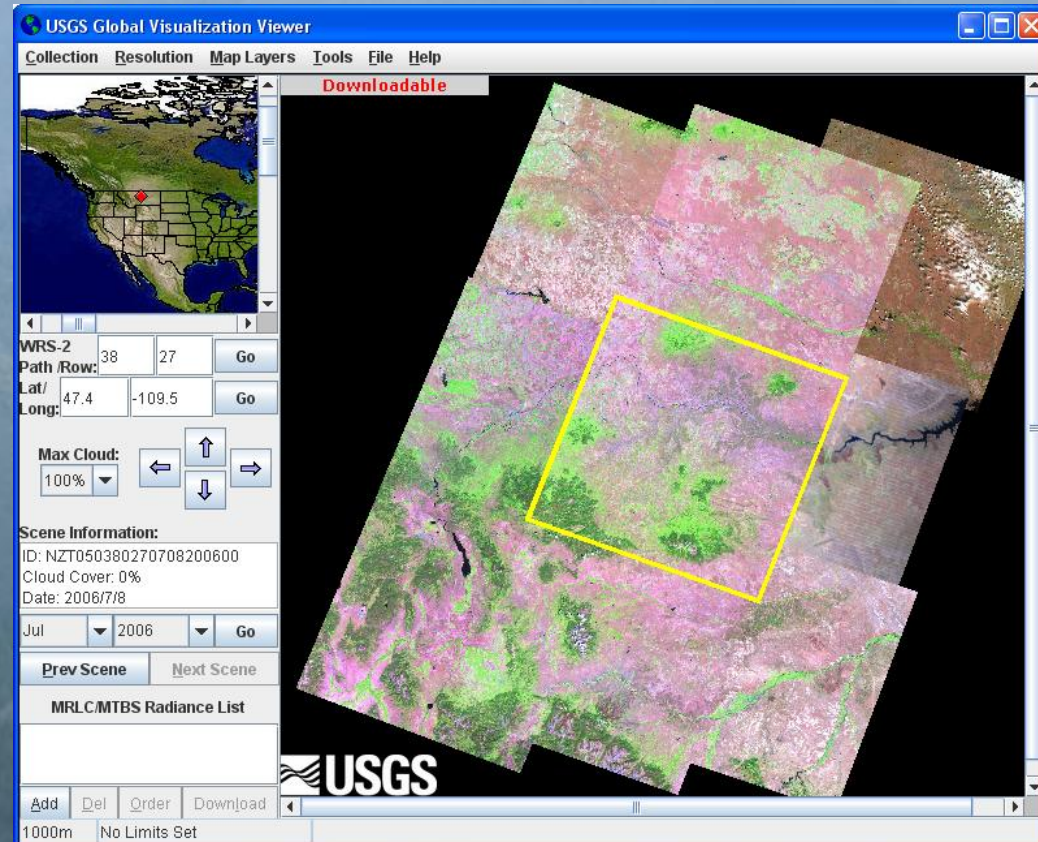
Landsat



- Landsat 1, 2, and 3 MultiSpectral Scanner (MSS) – 4 bands, 80 meter spatial resolution (1972-1983).
- Landsat 3, 4, and 5 carried both MSS and Thematic Mapper (TM) sensors (Landsat 4 1982-1992, Landsat 5 1984-present).
- Landsat 6 occupies a sub-aqueous orbit
- Landsat 7 carries the Enhanced Thematic Mapper Plus (ETM+), with 30m visible and IR bands, a 60m thermal band, and a 15m panchromatic band (185 km swath width) (1998).
- Landsat 8 (LCDM) planned for 2011

Glovis

- Search variety of image datasets maintained by USGS
- Several collections are free to download
- Tool used to distribute all free Landsat data



<http://glovis.usgs.gov>

CIDR

- <http://cidr.cr.usgs.gov/main.php>
- Mechanism for acquiring free high resolution imagery
- NOC can assist with defining requirements

Federal Civil Agency Implementation of the U.S. Commercial Remote Sensing Space Policy - Windows Internet Explorer

http://cidr.cr.usgs.gov/viewreq.php?id=1833&reqAgency=175

USGS CIDR

File Edit View Favorites Tools Help

Federal Civil Agency Implementation of the U.S. Com...

Details of selected requirement for Department of the Interior (DOI)/Bureau of Land Management (BLM) in FY 08

Requirement ID:	1833
Requirement Type:	planned data acquisition
Fiscal Year:	FY 08
Point of Contact (POC):	Matthew Bobo 303-236-0721 matthew_bobo@blm.gov
Department/Agency:	Department of the Interior (DOI)/Bureau of Land Management (BLM)
Program/Project/Requirement Name:	White River Field Office Monitoring
Project Description:	The White River Field Office is developing a plan amendment for oil/gas development. This plan amendment is calling for use of satellite imagery to monitoring the development over time.
Primary Mission/Application:	environmental monitoring and assessment
Observable(s):	NITF 2.1 is acceptable. WorldView-1 stereo imagery would be preferred for this requirement.
Requirement Mission Priority:	mission critical
Intended Method to Obtain the Data:	free source
Funding Partnership:	federal
Funding/Potential Funding:	\$0
Funding Confidence:	100%
Estimated Umbrella Requirement Funding:	\$60,000
Contract Funding POC:	Matthew Bobo 303-236-0721 matthew_bobo@blm.gov
Area of Interest:	blm_mesa_geo.shp blm_mesa_geo.shx blm_mesa_geo.dbf blm_mesa_geo.prj
Area of Interest Description:	The White River Field Office is developing a plan amendment for oil/gas development. This plan amendment is calling for use of satellite imagery to monitoring the development over time.
QC Area of Interest:	1833.shp 1833.shx 1833.dbf 1833.prj
QC Area of Interest Bounding Box: (lat/long degrees)	North: 40.1689211 South: 39.5474279 West: -108.6107824 East: -107.9290670
Square Kilometers of AOI:	2434.35000
Desired Spatial Resolution:	< 1m
Spectrum:	black and white
Platform Preference:	worldview-1
Other Platform Acceptable:	
Target Imagery Dates:	06/01/2008 to 09/01/2008 (Linear)
Latest Data Delivery Date:	10/31/2008
Max Days Delay (Acquisition to Delivery):	
Acceptable License Restriction:	federal state and county
Cloud Cover Max:	10%
Horizontal Accuracy Needs:	1:12000
Vertical Accuracy Needs:	
Vertical Accuracy DEM Needs:	
Processing:	ortho

Done

Navigation Menu(s)

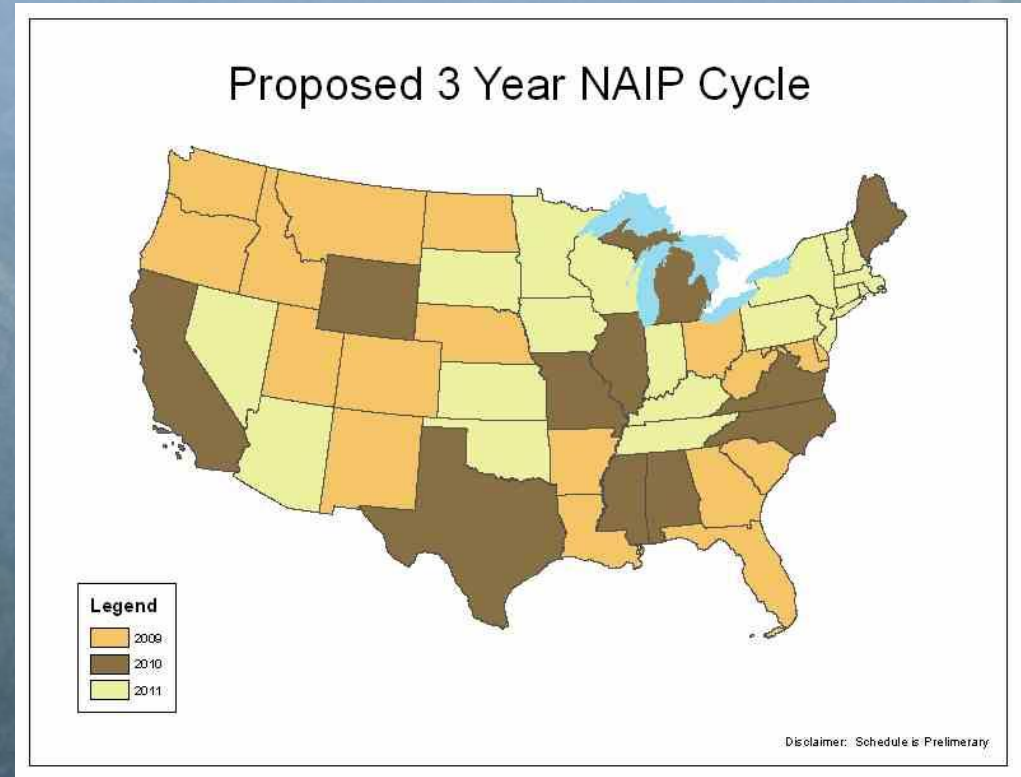
http://cidr.cr.usgs.gov/viewrequirements.php?page=1&orderCol=SPATIAL_RES

Internet 100%

Internet 100%

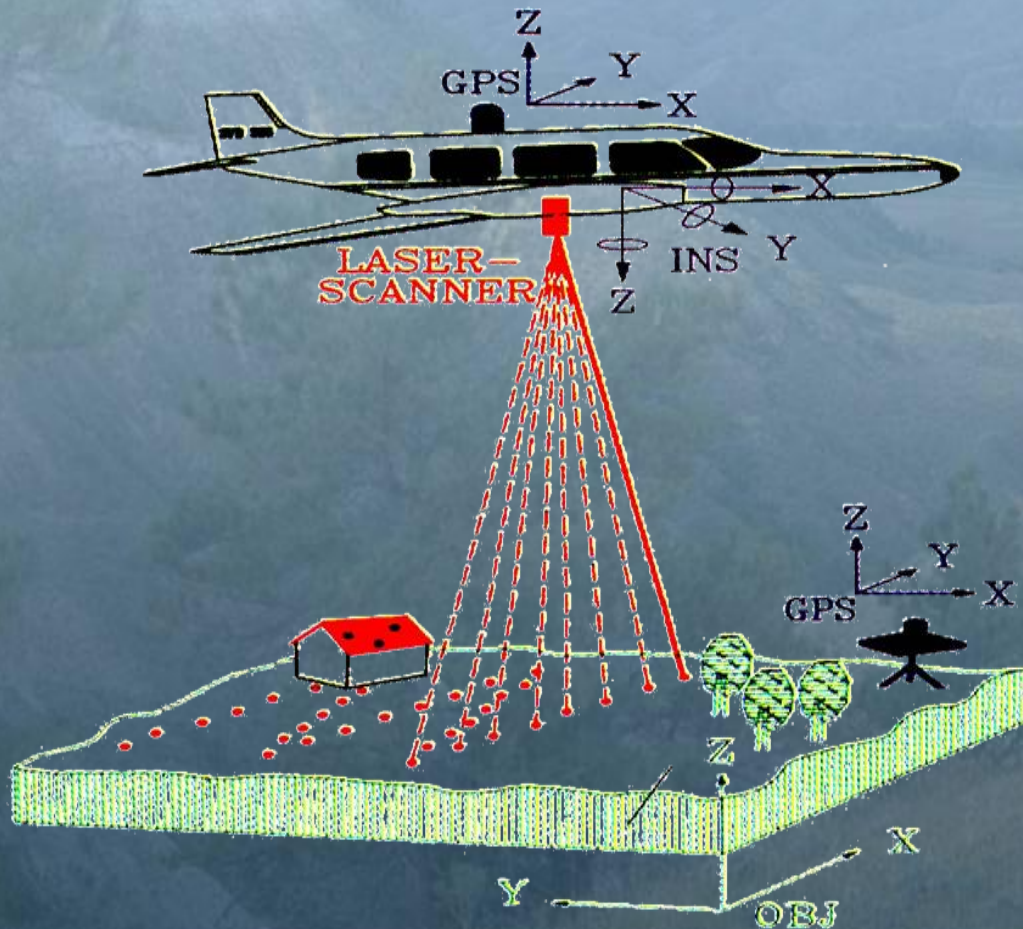
National Agricultural Imagery Program

- New Collection Schedule – Every 3 yrs
- WO secured funds for states
- Only AG lands guaranteed
- 15% premium for 4-Digital Orthos
- ~\$1.4 million for Idaho
 - \$215/DOQQ



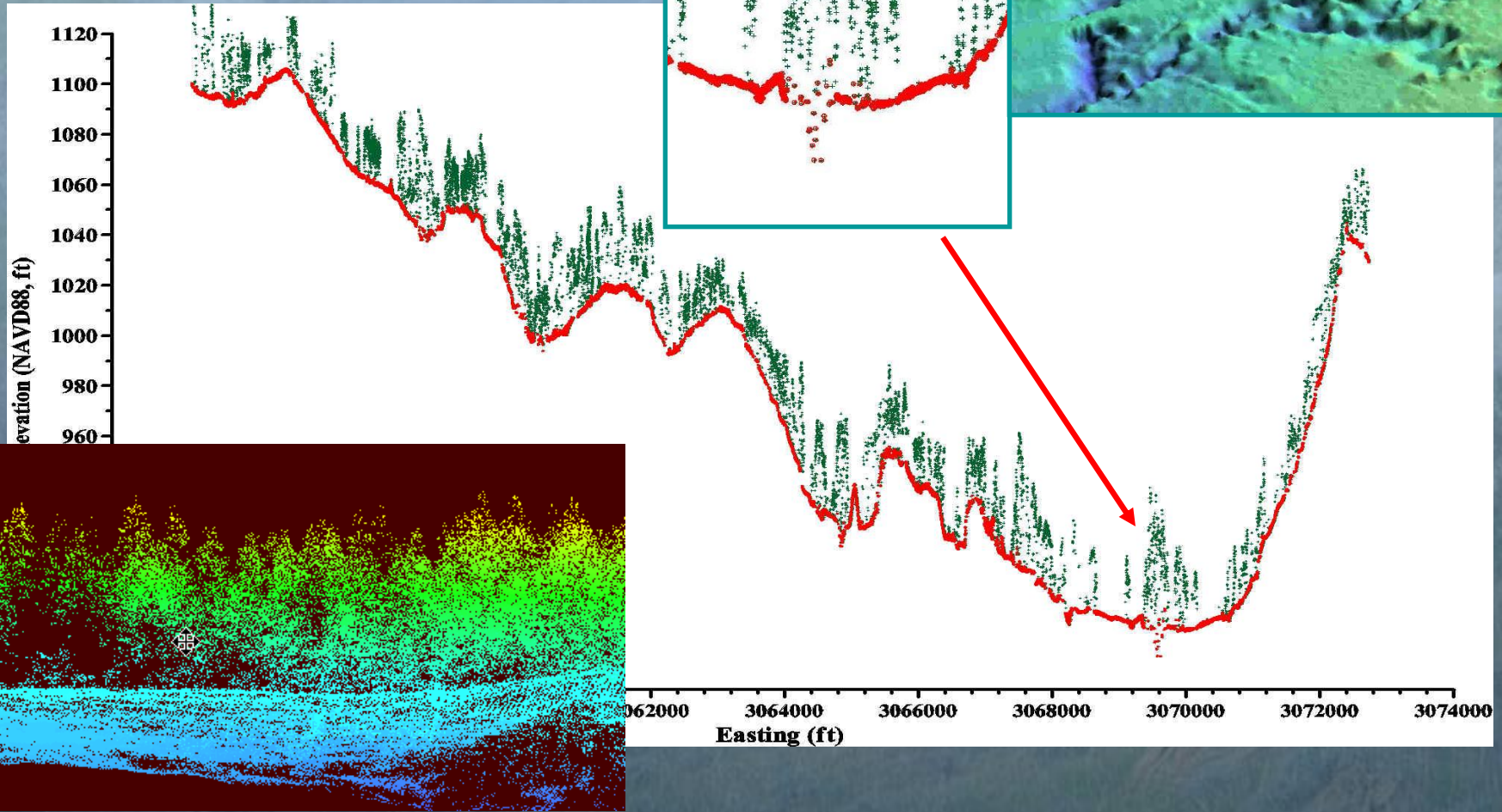
LIDAR

LASER-SCANNING



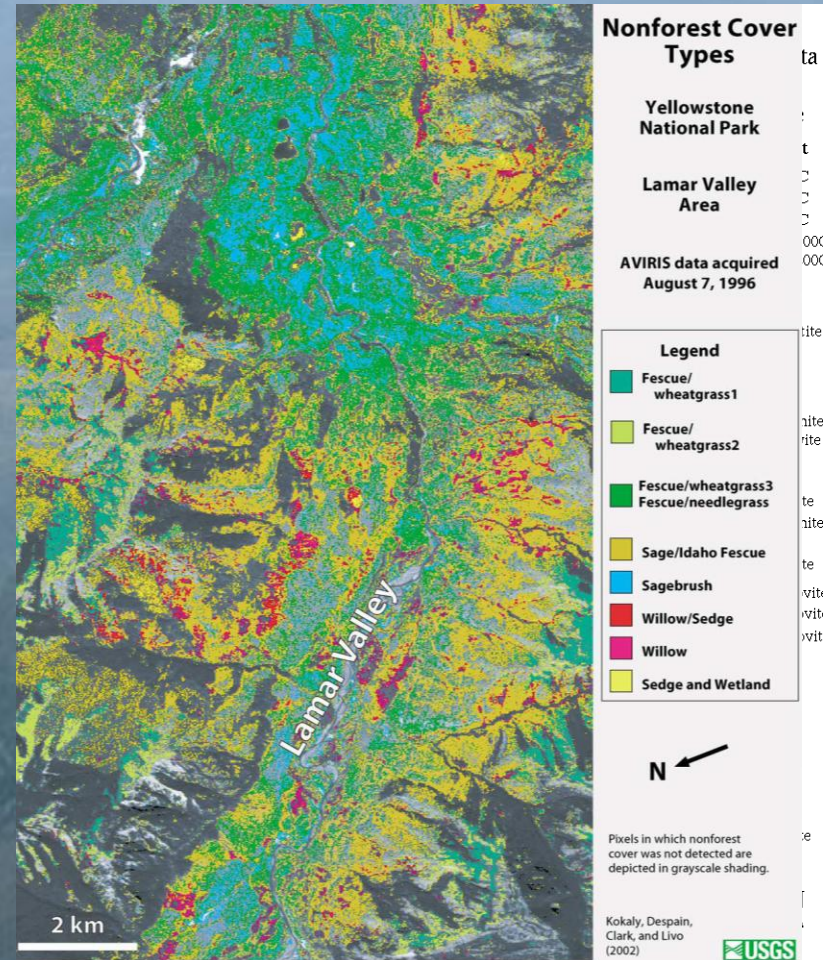
- LIDAR = Light Detection and Ranging
- Active sensing: can collect at night
- Timing of pulse gives elevation (DEM)
- Magnitude of return pulse gives intensity image (DOQ)
- Minimum of thousands of pulses per second (KhZ+)
- Multiple returns potentially from each transmitted pulse
- Costs are widely variable depending on size and complexity of project
 - Low of \$0.82/acre

LIDAR transect



Hyperspectral Remote Sensing

- Images in 100s of very narrow wavelength
- Much finer discrimination of resources
- Examples:
 - HyMap - 126 bands across the wavelength region of 0.45 – 2.5 nm.
 - ARCHER – Run by CAP
- Typical cost \$3.5k per 20 km line length with 5 m pixel size plus 5-7k for mobilization from Colorado.



We are Data Rich and Information Poor



Remote Sensing (POCs)

- Debra Dinville
 - Section Lead
- Russell Jackson
 - Leica Software Products
 - NAIP, NED
- Dave Kett
 - Aerial Photography Acquisition
 - Traditional Photogrammetric Processing
- Matthew Bobo
 - Satellite Imagery
 - Image Processing
 - Other IP Software Products
- Neffra Matthews
 - Close Range Photogrammetry
- Susan Goodman
 - Fire Related Geospatial Activities

Contact Information

Matthew Bobo

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Denver, CO 80225

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